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COGNITIVE PROCESSES IN INTELLIGENCE ANALYSIS: A DESCRIPTIVE MODEL AND REVIEW OF THE LITERATURE

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The descriptive model of cognitive processes in intelligence analysis presented in this report was developed as a part of a study entitled "Investigation of Methodologies and Techniques for Intelligence Analysis." The approach to constructing the model is based on the investigation of analytical processing in two types of single source analysis (SIGINT and IMINT), subsequently generalizing to multisource analysis. For the purposes of this investigation, intelligence analysis was defined as a spectrum of analytical and judgmental activities involved in the

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processing and production of intelligence, where particular individuals may devote more or less time to different aspects of such activities according to their individual roles in the intelligence cycle.

A production model of imagery intelligence (IMINT) was developed to serve as a basis for selecting IMINT processes involving high analytical and judgmental content for further study, directed at understanding the cognitive functions that underlie these IMINT processes. The IMINT model is presented in ARI Research Report 1210. A general overview of the project is published as ARI Research Report 1237.

The present paper contains a detailed review of selected aspects of current psychological literature, as well as the cognitive model which is based on that literature and on investigation of the IMINT and SIGINT production models. The cognitive model and the literature review focus on how information is processed, stored and retrieved from memory, evaluated and integrated to form intelligence. The model has general applicability to the full spectrum of intelligence processing activities.

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A

Intelligence collection systems have proliferated over the past several years, increasing in complexity and in volume of output. However, there has been no corresponding improvement in the ability of intelligence personnel to analyze this flood of data. US Army Intelligence and Security Command (INSCOM) studies and Army Research Institute (ARI) research indicate that improved support to and training of analysts are necessary to effectively utilize the increased collection capability and satisfy increasing demands for intelligence within current personnel constraints. INSCOM and ARI therefore initiated a joint research program to provide improved support to the intelligence analyst. During early discussions of the issues, it became clear that any procedural, training, organizational, or system changes to support analysis will be effective only if based upon a detailed understanding of the analysts' role, methods, and thought processes in intelligence production. The first need was to evaluate and describe the human analytic processes underlying intelligence analysis, synthesis, and production. This report contains a detailed review of selected aspects of current psychological literature as well as a descriptive cognitive model.

The approach taken in this project was to examine the role and activities of various types of intelligence analysts, and to develop a descriptive model of the cognitive processes involved in analysis. The cognitive model derives in part from current psychological literature and in part from an earlier effort under this project--Imagery Intelligence (IMINT) Production Model, ARI Research Report 1210. Not a new statement of psychological principles, the model puts these principles in a new context, intelligence analysis. A separate report provides a general overview of the project (ARI Research Report 1237).

The research was accomplished by a government-contractor team under contract MDA 903-78-C-2044 and was monitored jointly by INSCOM and ARI. Continuous interaction and collaboration of personnel from Operating Systems, Inc., INSCOM, and ARI insured a multidisciplinary approach to this research.

This report and the others from this project provide a framework for detailed examination of training support and system support requirements in intelligence analysis. These reports should be very useful during the development or evaluation of training procedures or materials, analytic procedures, doctrine, and system requirements for automated support to analysts.

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SAG Participants

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Cognitive Processes in Intelligence Analysis:
A Description Model and Review of the Literature

BRIEF

Requirement:

To review the psychological literature on cognitive information processing and develop a descriptive model of the cognitive processes underlying single-source and multi-source intelligence analysis.

Approach:

The development of the descriptive cognitive model was based on critical integration of knowledge obtained from review of the literature and individual interviews with military intelligence analysts. The literature review was focused on the latest research findings in the areas of human memory, perception, information processing, as well as judgment and decisionmaking. The interviews with intelligence personnel and analysts were conducted as part of a larger project investigating the processes of intelligence analysis (for an overview see ARI Research Report 1237). There was a total of 117 interviews with developers of training materials, image interpreters, signal and all-source intelligence analysts, in both garrison and field exercises.

Product:

The psychological model describes the cognitive processes believed to underlie intelligence analysis. The focus is on how information is processed, stored and retrieved from memory, evaluated, and integrated to form intelligence. The literature review supports the selection of these processes and provides the details of the nature, mechanisms, and relationships of the cognitive processes. A major emphasis is on the critical role of analysts' thought processes; while based ultimately on data, intelligence is actually created by the analyst. In other words, "truth" is seldom hidden in the data; it is constructed by the analyst, with the data playing a relatively small role.

Utilization:

This report is a detailed exposition and scientific justification of the cognitive model of intelligence analysis. It will help psychologists and psychologically sophisticated military personnel to better understand the underlying processes of intelligence analysis. Such an understanding will contribute to improvements in the quality of intelligence through training of both analysts and management as well as intelligence systems development. An extension of this model in the second phase of the project will support the development of improved analytic procedures and system specifications for the All Source Analysis System.

CONTENTS

COGNITIVE PROCESSES IN INTELLIGENCE ANALYSIS: A DESCRIPTIVE MODEL AND REVIEW OF THE LITERATURE

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ABSTRACT

This report presents the background research literature used in the construction of a descriptive model of cognitive activities underlying the activities of intelligence analysis. The approach used to develop the cognitive model combined available information on the way in which intelligence analysis is performed in actual work settings with available research findings in cognitive psychology. The first step was to investigate analytical processing as currently practiced in two types of single-source analysis, and subsequently to generalize to multi-source analysis. The initial interview and observation research investigated signal intelligence (SIGINT). A second investigation focused on imagery intelligence (IMINT) and resulted in a model of the directly observable activities of single-source IMINT production. A questionnaire interview guide was developed and used for deeper analysis of the two single-source disciplines and multi-source production activities.

A concomitant task reviewed literature from cognitive psychology for applicability to the research. A cognitive model was developed, and intelligence analysis activities were studied from the point of view of the model. A main finding is that effective intelligence analysis is a concept-driven activity rather than a data-driven one. Project results have implications for improvements in a number of areas of intelligence work.

The present report discusses the research literature in some detail. An earlier report provided an overview of the results of the project.

1. INTRODUCTION AND OVERVIEW

The purpose of this report is to review research literature used in the construction of a descriptive model of the cognitive activities involved in intelligence analysis. Project findings were summarized in an earlier report *[Human Processes in Intelligence Analysis: Phase I Overview]*

The aim of the project was to improve understanding of the cognitive activities underlying intelligence processing and production. While the intelligence cycle and associated activities are reasonably well understood, the activities that go on in the head of an analyst are not. The basic objective of the project was to develop a cognitive model that would provide a framework for the description of the mental processes used in intelligence analysis.

In order to pursue this research the definition was adopted that intelligence analysis is what intelligence analysts do. This was defined to include a spectrum of analytical and judgmental activities involved in processing and production of intelligence, where individuals assigned to particular roles in intelligence may spend more or less time in analytical activity, depending on the assigned role. It was assumed that a set of common analytical task processes exists that crosscuts the various intelligence disciplines such as SIGINT, IMINT, and HUMINT (intelligence from human sources). It was also assumed that the identification of these common analytical task processes was a key to identifying the core information processing functions of greatest importance to intelligence analysis.

The approach was first to investigate analytical processing as currently practiced in two types of single-source analysis, and then to generalize the findings to the multi-source analysis environment where possible. The initial task involved a preliminary investigation of signal intelligence to identify those SIGINT task processes which appeared to have a high analytical and judgmental content. The second intelligence discipline investigated was imagery intelligence. A production model for IMINT activities was developed, and selected IMINT task processes were compared with similar SIGINT task processes. This comparison generated a definition of common analytical task processes that crosscut the intelligence disciplines. Although a detailed, intensive investigation of HUMINT was not within the scope of the project, some observations of HUMINT analysts at work were made and several discussions were held with such analysts.

The most telling result of the research is the clear implication that intelligence analysis is conceptually driven as opposed to data driven. What is critical is not just the data collected, but also what is added to those data in interpreting them via conceptual models in the analyst's store of knowledge. The core functions of intelligence analysis involve the use of complex conceptual models. The ability to use such models is dependent upon individual capacities as well as upon environmental or work setting variables. Because both individual and environmental variables affect the analyst's cognitive performance, the model of cognitive processes underlying intelligence analysis must incorporate both kinds of variables.

2. THE COGNITIVE MODEL

2.1 Overview

The cognitive model presented here summarizes selected aspects of cognitive functioning that appear to be of central importance to the processes involved in intelligence analysis activities. Each aspect has also been the object of laboratory verification in the field of experimental psychology.

The cognitive model is an abstract description intended to summarize and account for behavioral and psychological observations and their relationships. The model serves to describe interrelated processes that occur inside a person's head when performing intelligence analysis. Cognitive processing is a continuum--some is superficial and some very deep. During superficial processing the individual is sometimes aware of the processing and sometimes not; during deep processing the individual is sometimes aware of the processing and sometimes not. Whether accomplished within or outside awareness, cognitive processing is a dynamic interplay of information from the senses and from internal memory.

The cognitive model presented here focuses on the flow of information through the cognitive "system". It describes inputs and processes operating on those inputs to produce outputs. The inputs may come from the external world or from internal memories. The model as presented does not account for all known phenomena or describe all known processes in exhaustive detail. It does provide a framework for understanding cognitive processes in intelligence analysis.

The cognitive model is summarized by the following three points:

1. An individual's initial cognitive processing of information from the environment is conducted within a few tenths of a second by mechanisms operating outside the individual's awareness (termed "automatic" processing.) As depicted in Figure 2-1, information enters through sense organs (eyes, ears, etc.) where it is converted to nerve impulses by automatic (outside awareness) processes and conducted to the brain. There, an automatic process rapidly compares the raw sensory information with information patterns already stored in the individual's memory. This is the COMPARE arrow in Figure 2-1.

   When a gross match is found, parts of the raw sensory pattern are automatically selected because of their similarity to features of the memory pattern and are combined with other elements of the information pattern from memory, shown in Figure 2-1 as the CONSTRUCT arrow. The resulting pattern of combined information, still outside awareness, constitutes the initial version of "meaning" (of a visual scene, of a pattern of sound, of a tactile pattern, etc.) Thus, all initial meanings represent active constructions performed by cognitive processing mechanisms operating outside awareness. As already indicated, such constructions are ordinarily accomplished within a few tenths of a second.

2. Many initial meanings remain outside awareness and trigger patterns of highly practiced adjustments that are also carried on outside awareness. Automatically

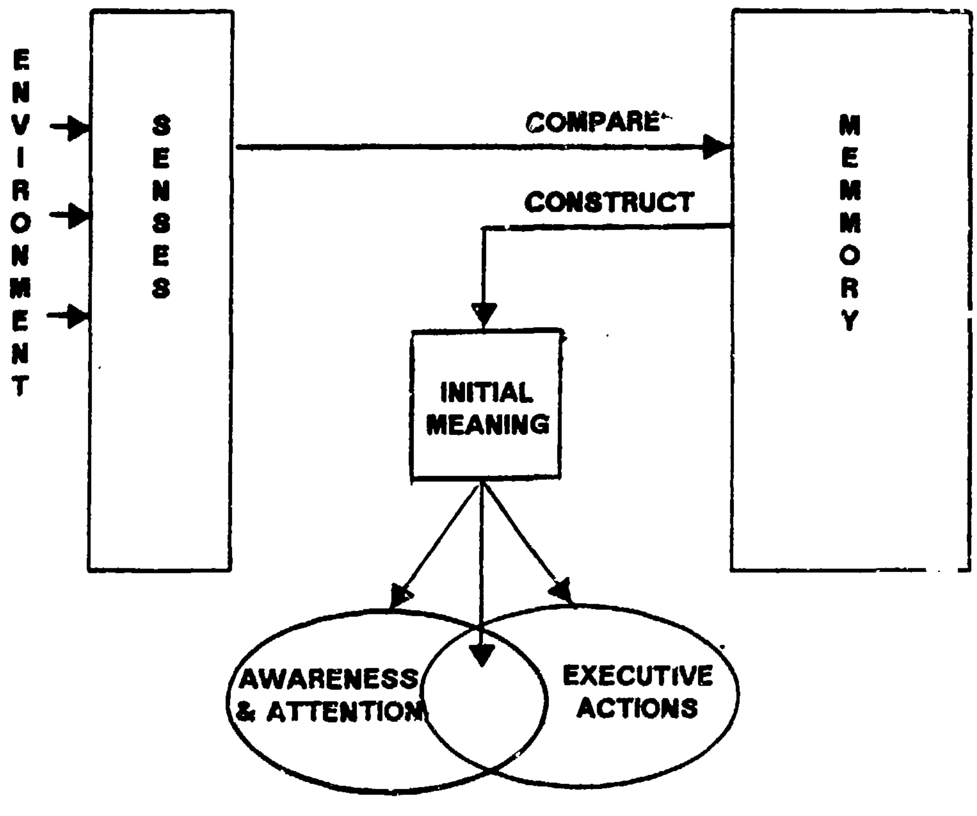

Figure 2-1. Cognitive Model Overview

constructed initial meanings form the bases for generating awareness (when awareness occurs) and for the initial selective focusing of attention on certain aspects of the aware experience. Such responses include automatically ignoring information as irrelevant, uninteresting, or completely expected.

3. The central cognitive function consists of a continuous cycling of the COMPARE/CONSTRUCT process, with each cycle accessing the individual's memory. Each cycle causes some modification of the memory-storage structure of the particular contents accessed. The modification of memory occurs regardless of whether memory information is used only for automatic processing outside awareness or is used also for deeper processing at progressively higher levels of awareness (such as paying close attention, studying a situation, thinking, decision making, and problem solving.)

Three main types of information modification occur as products of the functioning of the basic compare/construct process:

- sensory information filtering,
- memory information consolidation,
- memory access interference.

Analysis of an individual's experiences in terms of these modification mechanisms can provide predictions about cognitive information processing behavior to be expected from that individual. Thus, although individuals have little conscious control over the functioning of their memories and perceptions, the predictable relationships between experience patterns and information modification mechanisms can be used to predict and control the functioning of memory and perception.

The main cognitive functions just described are produced by basic, elemental processing dynamics operating through a structure of underlying cognitive capacities.

To summarize: Human cognition may be characterized as a set of interrelated processes which operate on available information. "Analysis" involves the assignment of meaning to incoming and previously stored information. The descriptive model of analytic behavior developed here builds on an understanding of some of these basic cognitive processes to explain analysts' interpretation, storage and recall of information. At a very general level the model describes the dynamic interplay between incoming information and previously stored information (i.e., internal memories). Processes which are central to this interplay are the COMPARE/CONSTRUCT sequence and the memory modification cycle involving filtering, consolidation, and access. At a more detailed level the model describes the functioning and implications of these processes and underlying processing dynamics.

In the following paragraphs, memory modification mechanisms are described first, followed by an account of the underlying structure of cognitive capacities and elemental processing dynamics.

2.2 Information Contents Modification Cycle

The COMPARE/CONSTRUCT processing of information depends upon elemental cognitive processing dynamics (to be described later) which operate continuously during wakefulness. The elemental dynamics support three *information modification mechanisms* that operate on the sensory and memory information used by the compare/construct process. Since information from the senses and memory constitutes the raw material upon which intelligence analysis interpretations and estimates are based, the information modification mechanisms have important implications for understanding and predicting the orientations and nature of analytic interpretations and estimates. Figure 2-2 diagrams the information contents modification cycle.

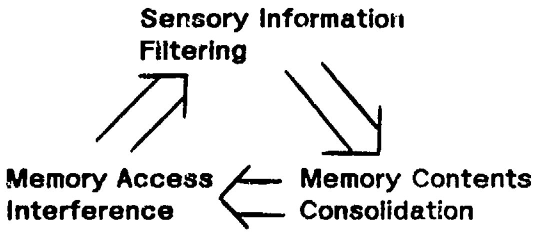

Figure 2-2. Information Contents Modification Cycle.

The cycle is composed of three mechanisms: sensory information filtering, memory contents consolidation, and memory access interference, all of which are described below.

2.2.1 Sensory Information Filtering

The *sensory information filtering* mechanism is composed of two complementary functions: **selectivity**, and **generalization.**

2.2.1.1 Selectivity Filtering

Selectivity mechanisms approach filtering from the viewpoint of answering the question: Which aspects of the raw sensory information pattern are significant? The compare/construct process outlined in Section 6.1.1 compares the raw sensory input for similarity with existing memory contents. An adequate gross match is usually found quickly, and the sensory input is relegated to an existing gross mental category.

Thus, the initial compare/construct process often **ignores** (passively rejects) significant information in the raw sensory input that in fact does not fit (at a deeper, more detailed level of analysis) the mental category assigned to it. If the overall first impression of the sensory information pattern is a good match with gross features of existing memory contents, disparities between the sensory pattern and the memory information pattern at more detailed levels often have no chance to enter awareness.

Polarization filtering is a variation of the selectivity filtering mechanism, in which an **expectation** that has been established usually increases the accessibility of memory contents related to that expectation (i.e., memory information related to both confirming and denying it). This produces a polarization effect that focuses more attention on the features of the expectation, thus passively rejecting other potentially important information that happens to be irrelevant for confirming or denying the expectation.

The polarization effect can bring positive results when unfolding events correspond to expectations and negative results when events are unrelated to confirming or denying expectations. Polarizing effects are stronger when an expectation is implicit (i.e., is unexamined or unquestioned in awareness). Explicit questioning of expectations can reduce polarization.

2.2.1.2 Generalization Filtering

Generalization mechanisms approach filtering from the viewpoint of answering the question: How much and what kind of similarities are required to recognize things as the same? The confident use of knowledge depends on being able to generalize from experience. Success in applying past experience (memory information) to the present depends on the validity of generalizations employed between the past and the present. The effective use of generalization is a fundamental and inescapable aspect of dealing successfully with the world. The elemental processing dynamics and basic capacities of the cognitive model (to be described later) provide the bases for identifying three main types of mechanisms for filtering by generalization: **tolerance, analogy, and fill-in.**

2.2.1.2.1 Tolerance Generalization

In *tolerance* generalization, a slot in a memory storage frame (see discussion accompanying Figure 2-5) is filled with new raw sensory information matching that slot. Generalization can occur depending upon the tolerance matching criteria of that slot. Since memory slots are organized hierarchically by increasing levels of detail of information stored there, tolerance requirements for matching grow more stringent at the deeper, more detailed levels of a memory slot. Of course generalization may be valid or invalid at any level, but looser tolerances increase the chance that raw sensory information is inappropriately generalized.

The mechanism of tolerance generalization usually operates outside awareness. Deeper, more thorough cognitive processing that involves more time spent in highly focused aware comparison between sensory information and memory information can prevent some of the errors introduced by the tolerance type of generalization.

2.2.1.2.2 Analogy Generalization

In *analogy* generalization, comparisons of similarity are made between the patterns of *relationships* connecting the slots of different memory contents storage frames. For example, the memory information about very different social organizations can be compared in order to generate analogies between organizational hierarchy structures; or memory contents depicting the relations between pressure, flow volume, and pipe diameter for water can generate analogies to memory contents for the relations between voltage, amperage, and conductance for electricity. The utility of generalization by analogy depends partly upon the actual relational equivalences between the real-world referents for the analogy, and partly upon the validity of the inferences drawn on the basis of assumed relational equivalences. The mechanism of analogy generalization often operates outside awareness.

2.2.1.2.3 Fill-In Generalization

In *fill-in* generalization, missing parts of the raw sensory pattern are filled in from similar chunks of information in the memory frame slot. If the *reasons* for missing parts of a sensory information pattern are implicitly understood, (either because they are obvious or because of insufficient consideration of the fact of missing information), the fill-in is often automatic. The results of fill-in are advantageous if sufficiently correct and disadvantageous if based on faulty assumptions. Careful examination of assumptions about missing data can raise the level of awareness used in fill-in processing.

2.2.2 Memory Contents Consolidation

Memory contents, including information recently passed through the filtering process and stored, are *consolidated* (i.e., made more accessible and vivid) as a joint function of the frequency of processing and the amount of attention used in the processing. Thus, more frequently encountered, important types of experiences upon which significant mental effort are expended become more vivid and immediately accessible in memory.

The increased accessibility and vividness of particular memory contents increases the likelihood that they will be used as filtering criteria in comparing/constructing future, somewhat similar raw experiences (versus using equally appropriate or more appropriate memory contents that are less accessible and less vivid). For this reason the contents consolidation mechanism can have important implications for the accuracy of analytic interpretations and estimates.

If the results of the consolidation mechanism match the realities of future events to be interpreted, the effects of consolidation are advantageous; if not, the effects are a disadvantage. Long term static conditions tend to increase the favorability of results from the consolidation process, while eras of rapid and significant change do not.

The caricature effect is a type of distortion that can result from the process of consolidation. Mental rehearsal of an experience, rumination about an experience, and problem-solving thinking about an experience can increase the accessibility and the vividness of the particular memory contents related to that experience. Given no additional external information about a certain experience, continued rehearsal, rumination, and thought tends to emphasize and deemphasize various aspects of the memory of that experience.

The result of emphasis and deemphasis is to "normalize" usual or expected aspects of the memory and to exaggerate unusual or unexpected aspects, with usualness/unusualness being judged in relation to the rest of the overall memory structure. That is, the consistency or usualness between some of the contents of the particular memory and the balance of memory contents may be exaggerated beyond their original consistency, and the disagreement and inconsistency in other parts of that particular memory may also be exaggerated beyond their original condition.

Since the combined results of these processes tend to produce a memory that is a caricature of the original contents, the result has been termed the *caricature effect*. This effect tends to feed on the elements of unusualness and surprise and to overweigh these elements as compared to the more expected elements of experience. If the situation is such that novel elements of an experience are accurate portents of a future similar event, the caricature effect may provide help in interpretation when it arrives. If not, the caricature effect can be an impediment to accurate interpretation, especially if the interpretation must be based on incomplete data.

The caricature effect is a special "no new information" version of the consolidation mechanism (the latter being based on repeated instances of a certain pattern of external experience). Since the caricature effect depends partly on the experience of initial surprise followed by a situation favoring the intensive use of unshared and unexamined rehearsal and rumination, the conditions for predicting and controlling the caricature effect are at present only partially understood.

2.2.3 Memory Access Interference

Memories for very similar experiences can interfere with one another during memory access, slowing access and making it less reliable and less accurate. (As indicated in the diagram of the modification cycle, such interference can have strong effects on the memory information available for the filtering stage of the next cycle.) The two main interference effects can be termed the **intervening similarities interference** effect and the **similarities saturation interference** effect.

2.2.3.1 Intervening Similarities Interference Effect

The requirement to access a memory of an earlier event may be either of two types: requirement for recall or requirement for recognition.

- Recall consists of, for example, responding to the question "What kinds of vehicles were present in the imagery you viewed before lunch yesterday?" That is, recall consists of accessing memory contents for a focus of attention of an earlier experience, based on receiving a name or description of the situation within which that focus of attention was experienced

- Recognition consists of, for example, responding to the question "Is this frame of imagery one of those that you viewed before lunch yesterday?" That is, recognition consists of accessing a memory for an earlier situation within which currently presented specific information was experienced as the focus of attention.

For both recall and recognition, highly similar experiences that have intervened between the original experience and the current requirement for memory access tend to interfere with the accessibility of the original memory material; the *intervening similarities effect* creates interference with memory access for both recall and recognition. Thus an analyst processing many messages of very similar contents from the same domain, under constant conditions and over an extended period of time, is unlikely to be able to recall the specific messages processed during a certain period of time. Also, the analyst may not be able to recognize a specific message presented for reexamination as having ever been processed.

When the intervening similarities type of memory access interference must be circumvented and can be anticipated, recourse to external memory aids is the only currently effective solution.

2.2.3.2 Similarities Saturation Effect

Concentrated repetitions of highly similar experiences cause proliferation of many highly similar memory contents in related areas of memory. The increased difficulty of comparing across and discriminating between many similar memories causes reduced speed and accuracy in the compare/construct processing of each new related experience. It also interferes with rapid and discriminable storage of the similar new experiences in memory.

The similarities saturation interference effect can be lessened by providing the individual a chance to refocus attention on **different** memory contents for a period of time, thus allowing the interfering memories to become less vivid and less immediately accessible. When the recovery phase has been accomplished, capacity is again available to learn new discriminations in that area of memory.

The intervening similarities and similarities saturation types of interference with memory performance are predictable cognitive mechanisms of information processing. They operate to weaken and diffuse the information available from memory by affecting the speed, reliability, and accuracy of access to memory contents. As indicated by the diagram of the modification cycle, such weakening and diffusion can change the pattern of memory contents that will be used as filtering criteria for the next cycle of experience and memory modification.

To summarize: Memory contents substantially determine the individual's automatic responses to, as well as aware experience of, new information. At the same time, the functioning of memory and of perception is not under the direct conscious control of the individual. Nevertheless, three potentially predictable and controllable cognitive mechanisms operate in a cycle to modify information contents available from memory. Since memory contents provide a large portion of the information used in making many intelligence analysis interpretations and estimates, the information contents modification cycle is an important concept for suggesting ways to improve intelligence analysis.

As part of this cycle information is filtered, consolidated and otherwise modified. Selective filtering may operate to ignore (filter out) aspects of information that are disparate from stored information. Polarization, stemming from expectations that have been established, may increase the chance of processing information that would otherwise have been filtered, but it may also lead to filtering of other information not directly related to confirmation or denial of the expectancy. Generalization is an important mechanism which operates during the filtering process.

Information which has passed from the senses through the filtering process is consolidated with preexisting information contents. The consolidation process provides a higher degree of access to information frequently called upon. However, it also may lead to various distortions of the information. Memory access is also affected by the structure of memory (the relationship of various kinds of information in storage). Attempts to recall (remember) information frequently encounter interference resulting from unavoidable confusion with similar information. It should be noted that these effects may be due to distortion during the initial storage process (the information was never stored as a discriminable item) or during the retrieval process.

2.3 Structure of Cognitive Capacities

The structure of basic cognitive capacities consists of information storage and routing facilities and their relationships, while the elemental processing dynamics consist of mechanisms for transforming information as it flows through the basic structure. From left to right, the column headings of Figure 2-3 depict the main components of the cognitive structure and their relationship to the analyst environment (the extended work setting):

1. Analytic Work Setting, including External Memory
2. Analyst's Senses
3. Analyst's Sensory Buffer
4. Analyst's Processor Structures
5. Analyst's Internal Memory

Each is described briefly below.

2.3.1 Analytic Work Setting and External Memory

Column 1 of the diagram in Figure 2-3 depicts the work setting, which contains many types of information channels. Information may be available through media such as face-to-face or telephone conversations, printed materials, computer-based displays, etc.

2.3.2 Senses

Various senses (vision, hearing, touch,) in column 2 are the means by which all information from the environment enters the cognition of the analyst. Each sense type can be distinguished by its receptor organ, the type of experience produced by the sense, the type of

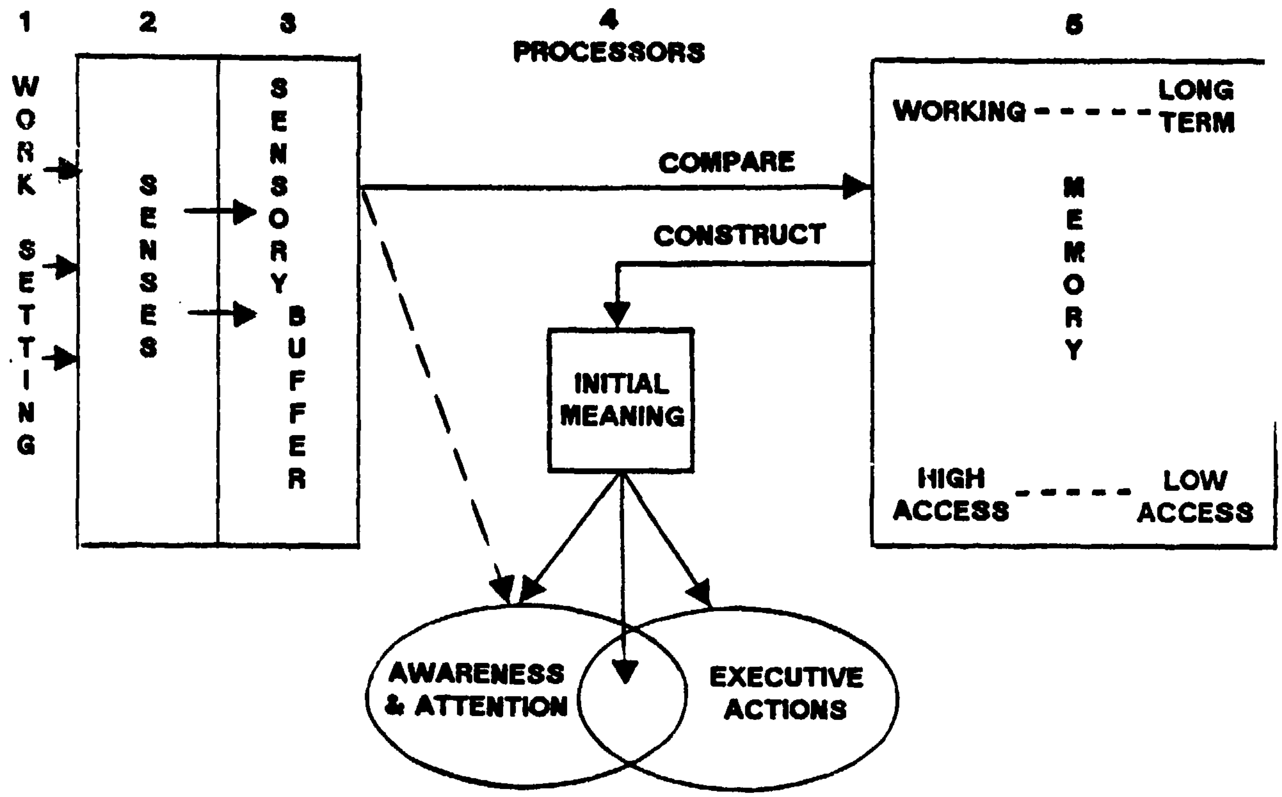

Figure 2-3. Cognitive Structures and Information Flows

physical energy to which the sense organ responds, and the information-carrying capacity of the sense.

2.3.3 Sensory Buffer

This capability (depicted in column 3) accepts raw information from the senses and makes it available to the rest of the cognitive structure, while at the same time preserving the information for a short time after cessation or change in the sensory input. The buffer has several characteristics:

- It *operates like a "push-through" store:* New information from the senses replaces or forces out older information after a certain (small) accumulation in the buffer has been reached.
- There is *partial parallel storage for different senses:* Traces for very recent auditory, touch, or muscular sense inputs outside awareness and attention can be recaptured by shifting the current focus of attention from, for example, the visual to the auditory. (The reader may be able to recapture unnoticed recent sounds.)
- Storage life *is very limited:* From one-half to two or three seconds

is typical.

- It may be *"commandeered":* Large changes in stimulus intensity for one type of stimulus can "swamp" the buffer capacity and momentarily eliminate the traces of other types of stimuli from the buffer.

- Buffer contents *are OUTSIDE awareness:* Buffer contents normally enter awareness only after they have been compared/constructed with contents from memory (i.e., are made meaningful) and often not even then. Thus, the focusing of attention (the choice of which sensory channel and material to attend to), is often accomplished outside of awareness. That is, the focusing of awareness and attention is accomplished both by processes within and processes outside of awareness.

2.3.4 The Processor Structures

Column 4 of Figure 2-3 contains COMPARE/CONSTRUCT processes which operate to transform the information flowing from the sensory buffer to the memory, and to route it back to the processors. Three processor structures are shown. The

1. *Awareness and Attention Processor* generates awareness and attention for information that flows through it. Conversely, all information flowing outside this processor is outside the individual's awareness and attention, and thus is processed by the:

2. *Outside Awareness Processor* which has a larger capacity than the awareness and attention processor.

3. *Executive Actions Processor* supports the production of external behavior.

These three processors combine their functions to produce:

1. External behavior within individual's awareness.

2. External behavior outside individual's awareness.

3. Internal, unobservable behavior within individual's awareness.

4. Internal, unobservable behavior outside individual's awareness.

2.3.5 Memory

Column 5 represents the overall characteristics of human memory as it is usually understood. It is critical to an understanding of human memory and of cognitive processes to realize that memory and thought are highly structured. Without categories and concepts, an individual would be unable to deal with incoming and stored data. A major aspect of the cognitive model, then, is the structure of memory.

- There is a high degree of correspondence between the categories of information available in the work setting and the categories of information in memory.

- For each category of analytic-relevant information contained in storage memory, there is also corresponding memory information indicating the availability (or lack of) supplementary information of the same category in the work setting.

- The accessibility of contents of memory varies with respect to speed of access, reliability of access, and level of detail of information available. The overall dimension of accessibility is depicted in the diagram by the scale shown at the bottom of column 5. Highly accessible contents are depicted as "closer" to the processor structures that will use them.

- Memory contents vary with respect to the amount of time they have been in storage. Although storage times are on a continuum, memory researchers have found it convenient to designate recently stored and/or recently accessed and re-stored contents as being in "working" or medium-term memory. Contents with long storage lives and less recent accesses and re-storage are designated as in "long term" memory.

- The amount of information potentially available from long term memory is much greater than in working memory. On the other hand, as indicated by the accessibility scale in the diagram, the information in working memory is more accessible than that in long term memory.

The *storage structure* of memory is uniform across its working and long term portions and across all categories of contents. The structure is built up from "chunks" of experience that are fitted into the "slots" of memory "frame" structures, as follows:

- An experience is organized as an *instance of a type* of something, occurring within an *instance of a type* of background setting (i.e., organized as instances of "figure" and "ground"); for example, a truck figure in a camouflaged position background or a division figure in field maneuvers background. The figure and the ground can be thought of as two gross "chunks" into which the experience is divided. Figure and ground chunks are often further divided and expanded into chunks at greater levels of detail (analogous to the effect of a zoom lens in the visual realm).

- The storage structures of memory consist of frames, each composed of a pattern of slots connected by links. Each slot represents a certain category of experience chunks already stored in memory and is organized hierarchically by increasing level of detail of the experience chunks stored in it. The examples in Figure 2-4 provide phrases describing information category chunks stored in memory frame slots, with progressively more detailed chunks at lower levels in the lists.

- A link in a memory frame is a special kind of slot that represents a certain type of relationship. For example, possible relationships linking two slots designated A and B would be:

  A: is part of B; succeeds B; occurs with B; implies B; is a subclass of B; is a functional equivalent of B; is synonymous with B; implies NOT B; was acquired with B; is associated with B; A and B are: parts of C; subclasses of C; etc.

VISION	HEARING
Vehicle	Moving vehicle sounds
Tracked vehicle	Tracked vehicle sounds
Light tank	Particular motor sounds
Topside	Particular track sounds
Turret	Combined Tank sounds
Turret hatch	Sounds of Specific Tank

Figure 2-4. Example: Hierarchies of Information Storage Chunks

Thus, both slots and links are categories of experience chunks already stored in memory, the categories each having a tolerance limit for accommodating similar new chunks of experience. Each new experience is represented as an "instance" of the category, with content variations appropriately appended.

- The contents of memory are outside awareness until they are accessed by the awareness and attention processor. Ordinarily, when being accessed by the awareness and attention processor, the chunks at various levels of detail in a memory slot are "opaque" to one another; i.e., two different levels of detail from memory do not occupy awareness simultaneously.

Figure 2-5 diagrams an example of a memory frame. Each of the two-way arrows represents a link between a pair of figure-in-ground slots. While all possible relationships between slots have been depicted in the diagram example, many potential relationships between slots in actual memory frames may be non-existent. The contents of slots in the example were selected somewhat arbitrarily from a larger set of possibilities, to help shed light on the concept of a memory frame, as follows:

Time locale slot: stores a time trace organized in terms of "before and after" relationships between chronological anchoring points for significant events, and being more fine-grained for recent experience.

Sensory slot: Often contains vague, general chunks for sensory experiences of vision, hearing, touch, taste, etc.; this is especially true in cases of more abstract experiences involving

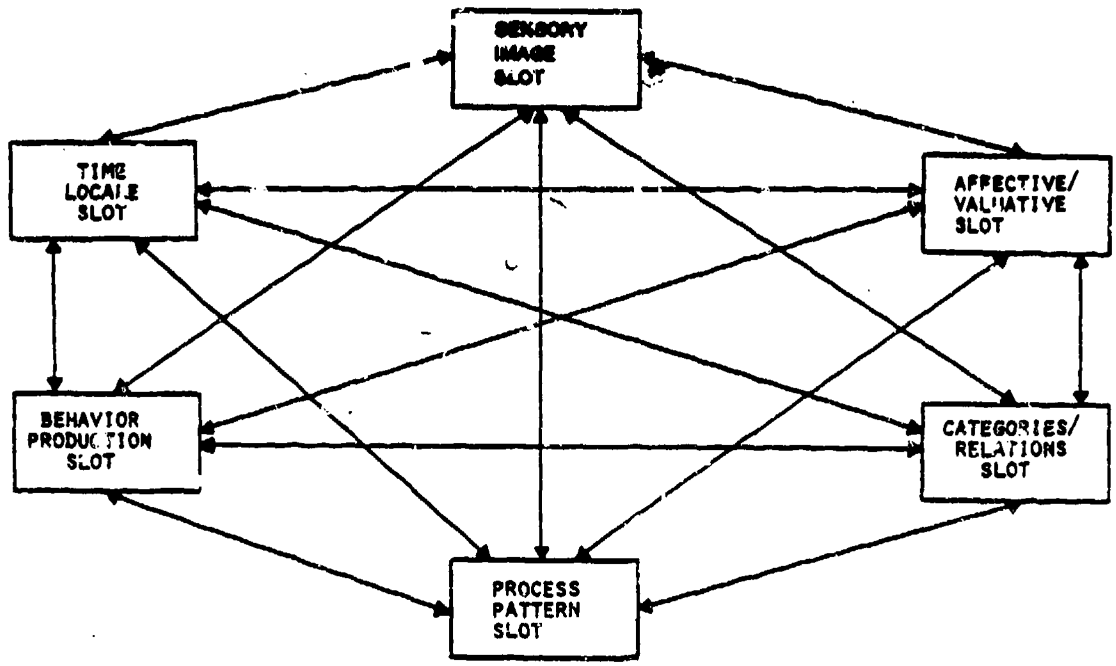

Figure 2-5. Example of Memory Frame Structure

information communicated via language or other symbols. On the other hand, the memory of, for example, a personally experienced motorcycle accident may include vivid sensory chunks in that memory storage slot.

Valuative/affective slot: Contains chunks representing value connotations such as goodness or badness, strength or weakness, and dynamic or static, as well as emotions such as affection, anger, or fear.

Linguistic categories/relations slot: Contains chunks representing linguistic/semantic descriptive categories and relations. Experiences originally conveyed via language and other symbols, and experiences that the individual has talked or written about, are more likely to have vivid material readily accessible in this slot.

Process pattern slot: Contains chunks representing "process phenomena" in which the particular linked instance of experience is understood as one step or stage of a larger, time-distributed process not directly experienced in the situation. The chunks in process pattern slots are a main source of expectations.

Behavior production slot: often contains little or no material. In instances where a type of experience demands external behavior, a chunk residing in this slot provides the outlines of "plans" for producing the required behavior.

Memory frames are the basic building blocks for higher-order storage structures of memory:

- A frame may operate as a slot in another frame.
- Superframes (systems of frames) develop, which systematize the storage of experience in terms of consistencies based on similarities between frames as well as other types of relationships between them.

To summarize: Raw information from the sense organs flows through the sensory buffer where it is retained only long enough to be accepted by the COMPARE/CONSTRUCT processes, initial phases of which operate outside awareness. These processes rapidly and automatically COMPARE the information input with patterns of information already stored in memory, and CONSTRUCT a meaning (a response) from a combination of the input and memory information. The initial construction of meaning takes place outside awareness within tenths of a second. The meaning may then be used to elicit actions, it may obtrude into awareness and drive thought processes, it may remain outside awareness and result in automatic adjustive reactions, or any combination of these.

Memory may be conveniently divided into a "working" memory, which stores current information for short durations, and "long-term" memory. Information in both parts of memory is stored in patterns called frames, which consist of slots, nodes, or chunks connected by links. The information in slots is arranged hierarchically by level of detail and specificity. The information in links represents types of relationships that hold between the information contained in the slots. A frame may comprise a slot in a larger, more incorporative frame, thus allowing for very complex memory structures to be developed.

2.4 Elemental Dynamic Processes

A brain trace representing an experience chunk exists in the form of a neural code; colors and sounds themselves do not exist in the brain but are represented there neurochemically. When stored in memory, the information represented by such a code is dormant. When a trace representing a chunk in memory is activated and the information represented by the trace is used in processing, the action is referred to as **decoding** the memory trace. Conversely, when an instance of an experience chunk is stored in memory in the form of inactive brain traces the action is referred to as **encoding** the experience. **Matching** is comparing trace codes for similarity. A match is an identified similarity between codes.

The basic compare/construct process described earlier (see Figure 2-3) is made up of more elemental dynamic processes consisting of a behavioral sequence of matching, decoding, matching, and encoding steps (MDME for Match Decode Match Encode). The MDME processes operate on the information flowing from the sensory buffer to the memory and back to the processor structures. In brief, in the MDME sequence, sensory information in the form of neural impulses is:

1. **matched grossly** against memory information. The memory information activated as grossly similar is then
2. **decoded** to a depth sufficient to ensure the degree of secondary match necessary in the particular situation. This compare/construct process produces a new configuring or "chunking" of information, which is
3. **encoded** in the form of new passive brain traces.
4. The newly constructed chunk of information also flows to other parts of the cognitive structure in the form of a Decoded Memory Return (DMR). The DMR may flow to the awareness and attention processor where it may program external behavior within awareness and/or match and decode other memory contents, including awareness of "no significant change." The awareness processor has a limited information processing capacity, and can focus close attention on only one level of detail of an experience at a time.
5. In thought and problem solving, the DMR often originates in cognitive activities stimulated by memory contents rather than by information from the sensory buffer.
6. The DMR may also flow to the executive actions processor, where it operates, in coordination with other behavioral plans information from memory, to program patterns of external behavior. The executive actions processor may operate in conjunction with the awareness and attention processor to produce aware, deliberate forms of external behavior. More commonly, however, the executive actions processor operates outside awareness to produce automatic external behavior in response to DMRs.
7. Under special conditions, raw information from the sensory buffer may momentarily force its way into awareness before being processed through memory by the MDME processes. As a result, there is momentarily no DMR, and the raw sensory information is therefore experienced as meaningless.

To summarize the MDME processes; Several points for application to discussions in the chapter following can be drawn:

- The awareness/attention processor has a limited capacity compared to MDME processes operating outside awareness.
- All information in normal awareness has been filtered and filled in from memory contents by processes usually outside awareness.
- Sensory data from the external world has no meaning unless filtered and filled in from memory contents by processes operating initially outside the individual's awareness.
- Factors that form and control sensory perceptions and attention are mostly outside the individual's control. This is also true of remembering and thinking; individuals cannot force their thought to contain exactly the desired contents.

To summarize the cognitive model: Memory contents substantially determine the individual's automatic responses to, as well as aware experience of, new information. At the same time, the functioning of memory and of perception is not under the direct conscious control of the individual. Nevertheless, three potentially predictable and controllable cognitive mechanisms operate in a cycle to modify information contents available from memory. Since memory contents provide a large portion of the information used in making many intelligence analysis interpretations and estima..ns, the information contents modificati..n cycle is an important concept for suggesting ways to improve intelligence analysis.

Memory contents are stored hierarchically by level of detail, with gross features and outlines of information at shallower, more accessible levels of storage, and fine details at deeper levels. A central compare/construct mechanism matches incoming raw sensory inputs to similar memory contents and actively constructs a composite return which drives behavior and experience. The compare/construct mechanism also matches inputs from one part of memory with those from another, thus allowing thought and problem solving without external stimuli. The basic memory storage frame structure composed of slots and links allows for very flexible, complex storage structures comprising super-frames and memory systems. The strategies and judgmental criteria used by the action executive processor and the awareness and attention processor are themselves composed of contents from complex memory structures. are themselves composed of contents from complex memory structures.

3. LITERATURE SOURCES

3.1 Introduction

The model presented in the preceding chapter is a simplified framework for integrating a number of diverse findings and theories from cognitive psychology. The cognitive model and its parts represent metaphors for portraying understandable outlines for some very complex processes, about which much information and varying shades of opinion can be found in the current psychological literature. The following pages present selected examples of literature sources supporting, amplifying, and refining the concepts presented in the cognitive model.

3.2 Cognitive Structure

3.2.1 The Senses

As presented in the description of the cognitive model, the various senses can be distinguished by the type of experiences they produce, by the types of physical energy to which they respond, and by their information carrying capacity. Although the details of functioning of specific senses, of sensation, and of sense perception are largely tangential to the main purposes of a cognitive model being developed for intelligence analysis, the present account will amend and augment several points about sense reception viewed in somewhat more technical terms.

In a paper reviewing and commenting on a century of research on sense perception, Gibson (Gibson, J. J. 1979) summarizes a current view:

- Different types of sensory receptors are especially sensitive to certain kinds of stimulus energy, but can also be triggered by other types of energy from which they are partly protected by the anatomy of sense organs.
- Sensations come not from a single receptor but from a group of receptors comprising a unit triggered by a pattern of stimuli.
- A sensation rests not only upon the ability to distinguish between instances of stimulation, but also on the ability to extract invariants from the sensory inputs.
- There are kinds of awareness for which no sense impressions can be discovered, such as some postural and movement cues.
- There are also cross-mode sensations, such as cutaneous impressions localized on the face of the blind which utilize auditory information in the form of the echo-latencies of footsteps.
- Far from being passive channels, sensory activities are integrated into active perceptual systems involving continuous adjustment of sense organs to extract information from stimulation.

In the diagram of cognitive structures and information flows in Figure 2-3, various senses are depicted as flowing in a "mixed" fashion into the sensory buffer. This is meant to reflect the fact that, in intelligence analysis activities, data for interpretation are often presented to cognition simultaneously through more than one sense (e.g., vision, audition, touch). Second, it reflects findings that inputs from different senses are integrated in the brain at the level of the association cortex, rather than the different sense data being relegated solely to centers responsible for processing each separate type of sensory input. This hierarchical pattern of neural integration provides the basis and rationale for successful experiments on visual prostheses for the blind, utilizing sensory substitution in which the brain converts patterns of touch impulses into quasi-visual experiences (Restak, 1979, pp 364-78).

The concepts gleaned from Gibson and from Restak together provide support for three refinements to the ideas sketched in the cognitive model. The first is that sense-based experiences, as they occur naturally, are most often combinations of different types of simultaneous sensory inputs. A second is that the concept of a pure "sensation" is a metaphor. It is useful as a contrast to help define, by negation, the complexities of the memory-mediated experiences resulting from even the purest, most experimentally isolated stimuli. A third is that the concept of "raw sensory data" as an undifferentiated flow from a "passive" channel does not adequately reflect the active, orienting aspects of sensory reception.

3.2.2 The Sensory Buffer

The sensory buffer is not a peripheral but a central nervous system function representing widely distributed brain activities. The concept of a sensory buffer as presented in the cognitive model is a metaphor used to summarize short-term parallel-processing and stimulus persistence effects obtained in studies on visual and auditory reception. A conclusion from an investigation of visual iconic memory by Di Lollo (1977) was that the persistence of an iconic image (a visual image persisting after cessation of stimuli) is the result of an ongoing feature extraction process at higher brain processing levels, rather than the result of a process of image decay at the retinal or next most peripheral level. The below-awareness processes involved in scanning and activating visual memories typically operate in the range of 100 to 200 milliseconds. The iconic image resulting from the visual reception input persists (remains activated centrally) only until sufficient information has been extracted from it to support recognition and interpretation (an adequate match in the MDME process), then the iconic "memory display" ceases.

Other evidence for the central nature of iconic image persistence comes from the work of Meyer and Maguire (1977). They used visual gratings with different spatial frequencies, presented in an oscillating on-off pattern with a constant 50 msec on period and a variable off period adjusted by the subject to achieve an appearance of continuous presence. When spatial frequency (density) of the gratings was increased, iconic persistence increased from 300 to 450 msec, indicating that the appearance of continuous presence was attributable to more central brain processes rather than to image persistence at the retinal level.

Studies of echoic memory (very short term auditory memory) have identified phenomena that show a good fit with the "push through store" metaphor of the sensory buffer. In the "cocktail party" phenomenon, auditory attention is switched from an attended to a previously unattended source when, for example, one's name is mentioned. This phenomenon shows that short-term parallel storage and processing of auditory stimuli can take place outside of awareness and the focus of attention.

The partial parallel processing capabilities of the sensory buffer are apparent in the effects produced by experimentally induced interference stimuli.

Typical investigations of parallel processing phenomena use interfering stimuli that produce divided attention. Triesman (1960) showed that an attentional set to listen to one ear does not completely eliminate the processing of interference inputs from the other. The incomplete (imperfect) selective attention process typically operates outside awareness. It allows the distraction stimuli to attract some attention, thus reducing the amount of attention available to the primary channel and causing interference with the main attentional task. The parallel storage (persistence) and parallel processing aspects of such auditory information reception operate at the levels of brain functioning that involve long-term memory.

In the Stroop effect, presenting the word (green) printed in red ink, for example, causes a lengthening of the reaction times normally found for verbalizing visually presented words. Keele (1972) showed that the Stroop type of interference occurs at vocalization time, being an interference between the decoding relations for the word (character string) memory storage pattern and the color stimulus memory storage pattern. In effect, the unexpected conflicting color stimulus impinges on an unattended channel, creating a partial diversion (a divided attention) which interferes with (but does not stop) the processing of words on the attended channel. Keele points out that the processing required to establish the relationship between a presented word and its "name" (code) stored in memory is automatic, in the sense that no conscious processing is needed to connect the visual input with the ultimate triggering of corresponding information stored in memory.

Distracting stimuli, however, do not invariably result in interference effects; they can create facilitative ones also. Dallas and Merikle (1976) propose that interference is caused by the process of switching to the different meaning contexts (in memory) that are required by some distraction stimuli. On the other hand, if distraction words are highly related and congruent with the primary channel words, (e.g., strongly related semantically) they may actually speed up recognition processing. Also, if primary channel words admit of alternative meaning interpretations, presentation of distraction words related to the various meaning alternatives tends to bias interpretations of primary words in the directions of the distraction meanings.

Posner and Warren (1972, pp26-27) summarize an extensive review of studies of sensory reception and meaning by a diagram. They depict the relation between access to (or stimulation of) meaning contexts stored in memory, and conscious (aware) processing. The diagram portrays consciousness (aware sense-related experience) as the result of an interaction between sensory inputs and long term memory contents, and emphasizes the importance of the contents of long-term memory for guiding attention, perception and recognition. That processes interfering with recognition involve long-term memory is also suggested by the results obtained by Dallas and Merikle. They found that larger response lags were caused by attending to a second channel when the subject believes a stimulus is occurring there, but in fact does not receive one. In this case, a searched-for alternative meaning context in memory fails to be activated (finding one would reduce the processing load of scanning to find one), and the attempt to establish an anticipated alternative context persists.

The subtle interplay between awareness, directed attention and inattention, and the organized context within which an item of memory resides is illustrated in results obtained by Foreit (1976). The tendency to best remember the last stimulus item in a presented string of stimuli (the recency effect) can be suppressed by presentation of a "suffix"-- a further stimulus item that the subject is instructed not to attempt to remember. Rowe and Rowe (1976) show that the suffix suppression effect obtained by Foreit operates only if the suffix is of the same type as the other stimulus items on the list, (i.e., is a word, a letter, a digit, a tone, etc., which involves the same area of memory as the other stimuli.) Baddeley and Hitch (1977) present convincing evidence that time is less important for supporting the recency effect than is the number of similar intervening events that have occurred since the "last" item.

The sensory qualities of stored memory information may correspond closely to the original experience upon which the memory is based. Acts of imagination (internally stimulated MDME processes) can manipulate and "transfer" such qualities from one memory structure to another. A high correspondence in such sensory qualities between memory material and new sense reception inputs can facilitate the speed of input processing. These three points are neatly demonstrated in results obtained by Geiselman and Glenny (1977). Subjects were familiarized with the voices of a male and a female speaker. Word pairs were presented visually with instructions to the subjects to say the words to themselves, either in the male voice, the female voice, or their own voice. A recognition test was then run, with the word lists being spoken by the male or the female speaker. Recognition was better where the test voice matched the voice rehearsed mentally by the subject.

Numerous studies of iconic and echoic memory provide findings similar to the examples cited above. A sample of these are listed in the bibliography. A conclusion from such studies is that, in the same sense that the convenient concepts of "sensation" and "raw sense data" are metaphors with limited explanatory power, so also the concept of "sensory buffer", although succinct, is not strictly accurate. The processing sites of "sensory buffer" phenomena are not, as suggested by the cognitive model diagram, actually located at peripheral points in sense reception channels. Rather, they are manifestations of widely distributed brain activities that are involved in the initial combining of sensory inputs with memory contents.

3.2.3 *Cognitive Processors*

The cognitive model depicts an awareness and attention processor, an executive actions processor, and an outside awareness processor, all positioned on the information flow paths connecting the sensory components of the individual to the internal memory.

The "processors" metaphor has several identifiable origins. Of least weight is the analogy to computer-like central processing units. The concept of an **executive actions** processor takes its main outlines from the idea of plans as regulating behavior sequences, as offered by Miller, Galanter, and Pribram (1960), and the idea of behavior production systems presented by Newell (1973) and Anderson (1976). The concepts of an awareness and attention processor and an outside awareness processor take their main impetus from models of recognition behavior in laboratory settings, and from a neodissociation theory presented in a book (Hilgard 1977) summarizing several decades of research on dissociation. Concepts of interconnected specialized processors in the brain, each functioning mainly within the confines of distinct levels and areas of brain anatomy (cerebellum, reticular formation, thalamus, R-complex, limbic and neocortical systems, left and right hemispheres, pre-frontal lobes, etc.) are presented by Restak (1979, Chapters 4,5, and 10).

In discussing behavioral plans and behavior production systems, Wickelgren (1979, chptr 12) discusses the concepts originated by Miller, Galanter, and Pribram, by Newell, and by Anderson. His summary points out that the most basic behavioral plans have as constituents a partially ordered set of elementary actions and their consequences, such as attending to particular visual locations, moving limbs, and recalling associations. A behavioral plan must be general enough to handle the variable consequences of its actions. Plans are stored in long-term memory. The encoding of the order of actions and their possible consequences is critical to many plans, while the order of components is usually less important for other kinds of memory contents. Wickelgren strives to eliminate the homunculus--the hypothetical miniature decision maker in the head, whom he believes is implied by the "test" elements in the behavioral plan flow-charts formulated by Miller, Galanter, and Pribram. He replaces the context-free code of the latter with a context-sensitive code, and replaces their test elements with "state" elements, thus eliminating decisions. He also differs with them in assigning a "ballistic" type of control to many highly practiced acts rather than utilizing their feedback type of control.

That the brain's cerebellum is a main site for the processing that coordinates sequential postural movements has long been known. That it is also intimately involved with psycho-social and emotional development and functioning has become clear recently (Restak, 1979, chptr 8). The phenomena of apathy, innervation, the breakdown of behavioral sequences, and the regulation of volitional control over behavior all appear to dependent on mediational processing accomplished by the cerebellum. This is not, however, to suggest a highly focused brain "site" for an "executive actions processor", especially in view of the major contributions to extended planning and foresight provided by the pre-frontal lobes (Restak, pp 28-30).

Support for the concept of an awareness and attention processor per se has come from several sources. Posner and Warren (1972 pp 34) introduce the idea of a

> *"single limited-capacity central processing system that integrates signals from all modalities. When this system is occupied by any signal, its capacity is reduced for dealing with any other signal or mental operation that requires its use.--For our purposes the use of this system becomes the central definition of a "conscious process" and its non-use defines what is meant by "automatic"."*

Atkinson and Joula (1973) presented a model that distinguishes two processes very like those of the automatic/conscious distinction. In the rapid, error-prone first stage processing of this model, the sense reception input is matched against contents in long-term memory to establish recognition strengths for the input in relation to various memory areas. In the second stage, the selected highest-strength memory area is searched by a limited capacity central processor.

Part of the theoretical formulations of a number of authors of the early 70's is the idea that, as compared to the conscious processor, the automatic (outside awareness) processor has a very large processing capacity (including the parallel processing capabilities cited earlier). Bower (1970) and Koler (1970) observe, for example, that skilled readers are unaware of all encoding short of the final meanings of textual passages being read rapidly (a very high rate of information processing). At the same time, more conscious, painstaking processing of the text takes place for difficult or confusing passages.

During sense reception, the switch from unaware to aware processor often takes place in fractions of a second. A surprise can cause such a shift. Measurements of cortical potentials evoked while anticipating, for example, soft versus loud clicks shows a characteristic "P 300" positive response wave to a false prediction or anticipation (a surprise), the wave peaking at approximately 300 msec after the missed click (Restak 1979, pp257). Furthermore, the P300 event-related potential (ERP) appears to be generated at the same high rates as "endogenous" decision processes operating in a signal-detection experimental paradigm. This is in distinction to "exogenous" ERPs (100-180 msec) that covary with the physical stimulus magnitudes in the same paradigm (Woods, Hillyard, Courchesne, and Galambos 1980).

However, when the surprise is of the kind evoking deeper more involved semantic processing, as in reading the sentence: "I take my coffee with cream and dog", a characteristic "N 400" wave develops, with a negative spike peaking about 400 msec after the surprise (Kutas and Hillyard 1980). While these results await a complete explanation, the 100 msec average difference coupled with the change of electrical sign for the two kinds of surprises appear to be reliable indexes to markedly different responses for orienting processes elicited by the qualitatively different situations. The cognitive model for intelligence analysis depicts the focusing of attention as under the control of processes both within and outside awareness. MDME processes (interpretations) take place both outside and within awareness, and the act of focusing attention may be viewed as a behavior component of a larger, more encompassing interpretive process.

That awareness itself may be comprised mainly of a high-level, generalized form of interpretive behavior is suggested by several lines of evidence. The contents and general qualities of awareness (mental imagery) show an orderly progression in development in the child, as observed by many investigators, most notably Piaget. Several lines of evidence that such changes in consciousness develop in tandem with the brain's growing capacity to support increasingly complex interpretations (MDME processes) are reported by Restak (1979 chptr 12). Processing capacity is a joint product of developing brain "readinesses" and the experiential laying down of encoding patterns that are highly efficient for processing certain ranges of sense reception inputs. In the same vein, cogent arguments have recently been made that the Spearman general factor (G) common to diverse measures of intelligence may represent a general capacity for attention and awareness, with larger capacities able to support the ready processing of interpretations (MDME processes) of greater complexity, no matter what their specific natures might be (Hunt, 1979, p. 31).

All this suggests that awareness and attention may be constituted of adjunctive components that are temporarily attachable to outside-awareness systems of interpretive responses (MDME processes). Such conscious components would be heavily supported by the contents of memory, and when activated might operate as "overlays" of meaning appended to the MDME processes operating outside awareness. That such conscious overlays from memory also function in their own right, independently of sensory reception, is indicated by the powerful and convincing patterns of apparent sensory experiences that can occur in the absence of corresponding outside stimuli. This is demonstrated by dreams, by hallucinations induced by various means, and by the reliable and reproducible results of hypnotic procedures.

Awareness and attention have been studied phenomenologically, i.e., from the point of view of descriptions of the contents and quality of experience. Viewed in this light, apparent individual differences in subtle qualitative aspects of awareness and attention are most likely attributable to generalized structures of unique meanings from memory. Several different organized systems of belief, information, emotions, and subtle qualitative differences in experience may be part of the memory repertoire of an individual. Often such systems may be somewhat incompatible, but are able to coexist within the loose purview of a more encompassing but inconsistent organization within memory (e.g. views on civil rights applied to self versus to societal elements perceived as undesirable).

Under conditions of forced confrontation and conflict between such incompatible personal belief systems, a active conceptual "barrier" may be interposed between them to relieve the apparent conflict. Such barrier mechanisms (part of memory organization) may be invoked in varying degrees by an individual, and without necessarily involving awareness. The barrier mechanism is, for many persons, also readily accessible from the "outside" by patterns of suggestion. In fact, an orchestrated-from-the-outside combination of suggested barriers and experiential contents, fabricated from the individual's own memory resources, can result in bizarre experiences for the individual.

The above concepts are supported by the results of decades of work on dissociation that is reviewed and reported in Hilgard's book (1977). Hilgard points out that dissociation is an everyday psychological mechanism that occurs in a variety of forms under many conditions. Dissociation is the active splitting of the experienced unity of consciousness into independent, coexistent, apparently non-communicating mental organizations or entities. Partial dissociation occurs in the parallel processing involved in divided attention. It occurs in "non-conscious perception", in induced-state-dependent learning, and in sleep-like states.

The mechanism of dissociation acts in the manner of an active barrier maintained between separated systems of thought and experience within the individual. Clinical syndromes involving apparent massive and persistent dissociation include: the isolation of memories from aware experience (as in amnesia); the blocking of current sense reception from awareness (as in hysterical anaesthesia, hysterical deafness, and hysterical blindness); the protection of memory-synthesized pseudo-sense experiences and concepts from contradictory sense reception inputs (as in waking hallucinations and delusions); and, the systematized use of such mechanisms (as in the development of "multiple personalities" exhibited by an individual).

During decades of investigations, laboratory versions of each of the above types of naturally occurring massive dissociation have been produced by the procedures of hypnosis. Hypnosis can often be induced in a willing participant by a sequence of:

1. Attenuating most of the participant's channels of stimulation (dim light, visual fixation object, silence or a constant low background buzz, relaxation and restriction of motion),

2. "Over-filling" the participant's remaining comparatively active verbal-auditory channel with a low but distinct and reasonably continuous line of speech,

3. On this channel, using "self-fulfilling prophesy cycles" of contents in the form of suggestions (please relax, you want to relax, you are now very relaxed; your eyes are tired of fixing on the shiny spot, your eyes wish to close, your eyes are closing; you wish to pay attention to my voice, you are paying attention to my voice, you hear only my voice; you want to cooperate and become hypnotized, you are becoming hypnotized, you are now deeply hypnotized; etc.)

The result of these procedures is an apparent growth and reinforcement in the hypnotic subject of a concept of progressively narrowing and focusing the attention on the voice of the hypnotist. This concept of "sensory narrowing" is reinforced and experientially validated by the accompanying relaxation, stilled movement, and attenuation of the visual channel through eye fixation on a target. As the condition of hypnosis progresses, the attention and consciousness-dividing dissociative mechanism that is ordinarily under the individual's conscious and/or automatic control becomes, instead, responsive to the contents of the highly focused and "comparatively amplified" reception channel carrying the hypnotist's suggestions.

At this stage the creation and suppression of the subject's patterns of experience become more or less completely under the control of the hypnotic suggestion stream. Under this condition, the dissociative mechanism can, for example:

- Bar ordinarily intolerable pain from the subject's experience,
- Protect a suggested illusion that a touch is a hot iron from contradictory sense reception information,
- Bar hearing, vision, touch, or muscle sense reception inputs from awareness,

- Block the contents of memory from experience.

For purposes of the present discussion, such hypnotic and dissociation phenomena provide emphasis for the following points:

- The concept of separate processors for cognitive processing within and outside awareness is a reasonable, though somewhat loose, metaphor for summarizing the variably complete dissociative compartmenting and parallel operations that occur in much normal cognitive processing, and which are highlighted in extreme versions by hypnotic dissociation phenomena.
- The processors themselves consist of programmed sequences of MDME elemental processes controlled intrinsically by the contents of memory.
- The main or definitive common contents of the various experiences of awareness and attention are themselves highly organized products from memory, that can be attached and detached from the contents of sense-reception channels.
- Sensations (in line with Gibson's conclusions cited earlier) are active central constructions. Sense-reception is not passive, but rather a dynamically controlled orienting and seeking activity.
- The strategies, tactics, and missing ingredients used in the cognitive processing of sense reception inputs are overwhelming determined by the organization and contents of memory.

3.2.4 *Memory*

The memory structure depicted in the cognitive model is based on three concepts:

1. Duration of memory retention, with working and long-term memory as convenient names for overlapping regions on a continuum of retention of memory contents.
2. Memory frame, with the slots and links of the frame providing a metaphor for the observed association of various types of memory contents into cohesive units.
3. Memory hierarchy, with degree of information detail being the organizing principle for "chunking" a given instance of a pattern of a specific type of information into several different hierarchically arranged levels of stored detail.

3.2.4.1 *Working memory*

Working memory is typified by the type of memory capacities used in storing information from a currently unfolding real-time scene which may or may not involve problem-solving and actions on the part of the individual. Durations of information retention may vary in working memory from about two to about fifteen seconds. Unfolding real-time scenes can vary between the extremes of a jumble of disconnected, arbitrary-appearing events to a fixed, highly familiar, ritually organized tableau. Working memory is a metaphor for a range of retention processes that show varied degrees of organization and durations of retention.

Atkinson and Shiffrin (1971) describe a rehearsal buffer which provides part of the memory facilities used by a limited capacity conscious processor in performing programmed sequences of executive actions. Shiffrin and Schneider (1977) re-conceived the rehearsal buffer as an activated subset of long-term memory. Craik (1979) criticizes Shiffrin and Schneider's concept of the operation of the rehearsal buffer, that at input all features of incoming stimuli are analyzed and appear as active elements in long term memory. In the Shiffrin-Schneider view, most activated elements drop out immediately because they are not attended to after initial activation. Craik, however, believes that for reasons of processing economy and biological efficiency only a fraction of the many possible combinations of interpretations of the input become "activated". (This is the view adopted for the MD sequence of the MDME elemental process presented in the cognitive model.)

A widely held concept for the operation of working memory (short-term memory, rehearsal buffer) is that activated (Matched/Decoded) elements of sense reception inputs remain in their initial form until they can be encompassed (reencoded) as parts of established meanings (memory organizations) Collins and Loftus (1975). There are many varieties of initial forms; for example: a list of recognized letters, a list of nonsense syllables, the string of words making up a not-understood sentence, an instantly understood sentence, a strange animal or machine, a recognized type of animal, the face of an intimate friend, a view of one's house, etc. The mental act of rehearsal allows such initial forms to be refreshed or reactivated as they decay, to be reencoded as established meanings, or both.

Encoding can include categorizing the presented items, encoding their order of presentation, or combinations of categorization and order encoding. Murdock (1976) found that memory for items on a list is improved if all items presented are from a single semantic category, but that memory for presentation order of the items is better for mixed-category than for single-category lists. Whether one form of encoding interferes with the other, one serves as a functional substitute for the "need to encode" the other, or the encoding alternative involving least effort is used, is not clear. The idea that the rehearsal buffer (working memory) can provide parallel processing access for several distinct forms of specialized attention is suggested by results obtained by Roediger, Knight, and Kantowitz (1977) and Peterson, Rawlings, and Cohen (1977). The former found no differences in the retention of five words while performing easy or difficult perceptual-motor tasks. Peterson et al found that rehearsal in visual-spatial memory could proceed concurrently with verbal rehearsal. Thus several different systems of "active tags" may be able to co-exist concurrently in memory, with the total available processing capacity being flexibly split (dissociated), and rapidly allocated according to very complex dynamic behavior programs.

Estes (1980) shows that the time required for the mental operation of retrieving from long-term memory a newly learned association between two characters is about 200 msec, and from short-term memory about 25 msec. He provides evidence about the organization of short-term memory from experiments in which subjects attempted to recall characters from a previously presented string in the order of their presentation, and in addition diagramed the positions of the characters. The characters appear to be retained in short-term memory not as discrete items in fixed positional slots, but rather as "uncertainty distributions" that show (via positioning errors) some overlap immediately after presentation, and increasing overlap as a function of time between presentation and recall trial. Estes postulates that the precision of information about an event such as sense-reception of a character is slowly lost over time. He proposes that the capacity of human short-term memory only appears to be small when it is measured in terms of discrete items, such as letters or words. In contrast, he characterizes the general nature of human memory:

--the human memory seems strongly to prefer an analog mode in which information of varying degrees of precision or levels of specification concerning attributes of events are stored with relatively high redundancy, so that at least partial retention of information about an experience is likely even if the system is grossly disturbed, as by disease or injury.--it seems to be not at all like a storeroom, a library, or a computer core memory, a place where items of information are stored and kept until wanted, but rather presents a picture of a complex, dynamic system that any given time can be made to deliver information concerning discrete events or items it has had experience with in the past. In fact, human memory does not, in a literal sense, store anything; it simply changes as a function of experience. (p 68)

The preceding points add complexity to the view of the cognitive model as presented earlier. The model depicts the within-awareness (conscious) processor as of limited capacity and limited dimensionality in comparison to the outside-awareness (automatic) processor. The above discussion suggests expanding the capacity and dimensionality of the within-awareness processor from that originally presented, thus softening somewhat the distinctions between the aware and unaware processors. It also suggests that part of the apparently greater capacity of the automatic processor may be due to the shallower (grosser) level of encoding at which it characteristically (though not necessarily) operates in scanning and activating (matching) memory contents. Another part of the greater apparent capacity of the automatic processor may accrue because it is not required to support conscious experience overlays from memory, which may impose a variably taxing load on within-awareness processing.

3.2.4.2 Long-Term Memory

The concept of unitary memory patterns such as formats, schemas, or **frames** (as they are designated in the present cognitive model) has a history going back at least to the "schemas" of Bartlett (1932). Common to these conceptions have been two components of storage that make up unitary memory patterns. The first has been variously named node, slot, feature, or chunk and comprises or contains a memory image or trace pattern representing an organized aspect of experience (whether sense-reception based or mentally synthesized). The second is a generalized link, connector, association, or relation that brings the first type of components together into an identifiable pattern of memory.

As suggested by the cognitive model, the chief expositional function of the concept of frame-like memory structures is to depict the organized aggregating and juxtapositioning of distinctly different kinds of mental contents. The contents within a frame often include imagery based on different sense modalities. This is attested by the results of psychological experiments on memory and learning, (Shiffrin and Grantham 1974), as well as by findings from studies of brain functioning. The latter provide support for multi-sense integration at high levels of brain organization, for considerable functional "equipotentiality" for different cortical areas of the brain, and for partial functional substitution between senses under appropriate conditions (Restak, 1979, chptr 18), (Bross, Harper, and Sicz 1980).

The memory frame presented in the cognitive model implies that traces may be encoded for each of the sense modalities that respond during the experience; i.e., the frame diagram implies a multi-coding theory. Paivio (1967) presents a dual-coding (imaginal/verbal) theory, postulating that a visual image is more likely to also generate and be encoded as a verbal name, than a verbal image is to also generate and be encoded as a visual image. D'Agostino, O'Neill, and Paivio (1977) present evidence showing that dual coding occurs relatively automatically for pictures, but that only verbal coding is likely for abstract words for which images are undeveloped. Nelson (1978) shows that under conditions where words are phonemically distinctive and pictures are confusing, words may be retained better. Nelson suggests that, as compared with words, pictures usually induce a more detailed representation in memory. The issue is complicated further by findings of Siple, Fischer, and Bellugi (1977) that suggest that deaf persons encode known gestures from the American Sign Language in a semantic (verbal) form, and other gestures in the form of imagery. Dhawan and Pellegrino (1977) discuss variables and situational factors that can impact on the mix of encoding that may occur for a particular experience.

A hierarchical organization for memory frames of visual scenes is suggested by results from Mandler and Ritchey (1977). Recognition over four months was stronger for the contents of better organized (more typical or sensible) pictured scenes than for atypical ones, but only for more generic types of contents such as an inventory of objects and their spatial relations. Recognition of more specific descriptions of objects and the composition of the scene was not improved for better organized scenes. Patterson and Baddeley (1977) report similar results for the recognition of faces, in which rating faces on judgments of personality produced greater subsequent recognition levels than rating faces on physical characteristics such as size of nose.

Interactions within memory frames between semantic and visual imagery information chunks is depicted by results obtained by Loftus, Miller, and Burns (1978). The words "smashed" and "hit" were varied in otherwise identical written questions about a cartoon picture of a car accident presented earlier. For subsequently presented very similar but altered cartoons, the word "smashed" biased recognition errors significantly more toward those depicting greater crash impact and more damage.

The many possible semantic meanings of a single word such as "structure" are likely to be associated with different frames in an individual's memory. Thus in word association experiments, a word presented alone will produce different patterns of associative responses than when presented in a meaningful sentence context (Baker and Santa 1977). Moreover, Till (1977) showed that the effectiveness of a word or phrase as a cue for retrieving (recalling, recognizing) a sentence is typically based on complex inferences about the meaning of the sentence rather than on the superficial (surface structure) aspects of the sentence.

The effects of frame contexts persist into even more complex systems of frames involved in memories for stories. Bellezza, Cheesman, and Reddy (1977) found that linking a list of words together in a coherent story enhanced later recall of the words more than generating separate sentences using the words, or defining each of them. Rumelhart (1977) developed a "story grammar" composed of frame-like structures set in hierarchical relations, the highest (most generic) nodes having names like cause, try, and outcome. In turn, each such node subsumes various types of causes, of trials, of outcomes, etc. Such a structure can be used to predict patterns of recall for stories, and to predict the shifting of learning over repeated experiences with a story, from serial order effects to the hierarchically organized acquisition of meaning constituents as isolated by the grammar. Thorndyke (1977) and Mandler and Johnson (1977) describe similar results using other forms of story grammars.

In a similar vein, the dependence of visual memory for a scenario on higher-order frameworks for organizing events into a meaningful whole is shown in an experiment by Kraft and Jenkins (1977). Slides showing different steps or phases of a story-like scenario were shown in correct sequence and in jumbled sequence to different groups of subjects. For jumbled sequence subjects, those able to form a coherent story from the jumbled slides were later able to place new "intervening" slides never before seen into correct sequence for the scenario. The metaphor of a "process pattern slot" in the memory frame diagram of the cognitive model is intended to suggest these kinds of memory patterns.

The cognitive model also portrays the idea that experiences typically are encoded (stored in memory frames) as instances of certain types of phenomena occurring in certain types of contexts, (i.e., in a figure-ground relation). Flexser and Tulving (1978), and Craik (1979, pp 89) address the reasons for the anomolous condition in which an earlier-experienced stimulus object may not be recognized as such, but still may be recalled. The anomolous unsuccessful recognition may represent an inability of the presented item to match and decode the original episode-specific context of the earlier experience. The anomolous successful recall may represent the ability of the description (naming) of the episode-specific context to decode the episodic context memory chunk, (the "ground"), coupled with the ability of the linkage between the background memory chunk and the item memory chunk to reactivate (decode) the item chunk (an apparently more complex process than recognition).

This is the view of recognition and recall adopted in the cognitive model presented here. In this view, correct reactivation of the one-item-to-one-context linkage involved in recognition would be more reliable than reactivation of the correct linkage among the one-context-to-many-items linkages posed in recall. This is in fact the result most commonly obtained in experimental paradigms in which a list of similar items is presented in one episodic context. Such results support the concept of a typical figure-ground patterning of the memory contents stored for events (episodes). The functions of the item of attention (figure) and the episodic context (ground) of such memory structures in mediating the more nebulous uses of memory information for metaphors and analogies are considered by Verbrugge and McCarrell (1977).

The cognitive model depicts the slots or chunks of the memory frame as being hierarchically organized by level of detail of the type of information contained in each slot, with the higher more superficial levels containing gross generic categories and the subordinate deeper levels more fine-grained, specific information about the same conceptual categories. Mischel (1979) summarizes findings concerning the natural classifications of persons by discussing the idea of "cognitive economics". The person's system for classifying other individuals must provide efficient and personally meaningful "pigeon-holes" for others, and at the same time avoid apparent conceptual contradictions. How this tradeoff is accomplished depends upon the contents of the person's social environment,--the psycho-social ecology of the individual's social surroundings. Depending upon such factors, some of the individual's person-categories may be very inclusive with very little elaboration of subordinate concepts. Other categories may be quite highly refined.

In presenting the concept of a memory schema, Evans (1967) emphasizes the notion of a prototype around which the examples constituting the contents of the schema are organized. A very similar idea was expressed by Hull (1920) in discussing his studies of concept formation using chinese characters. In everyday life, conceptual categories are not formed by the presence of a few attributes invariable for all examples of the concept, but by many frequently present ones which are highly associated with each other, and highly associated with membership in the category. Both Hull and Evans found that a person can discover the prototype pattern within a concept on the basis of receiving only camouflaged, partial, or systematically distorted versions of the pattern. Bransford and Johnson (1972), and Rosch, Simpson and Miller (1976) have obtained similar results and offered similar explanations. The properties common to the different examples define the attributes or dimensions of similarity used to construct the prototypical central pattern governing the conceptual schema.

Tversky and Gati (1978) and Rosch (1978) present two similar but distinguishable accounts of the main factors contributing to the development, maintenance, and usage of conceptual categories. Tversky and Gati introduce the ideas of salience and diagnosticity of the features of objects. A feature attains salience as a function of its degree of diagnosticity for the particular environment (psychological ecology) within which it appears. A feature acquires diagnosticity within an environment on the basis of the degree to which its presence/absence in various concepts is correlated with the magnitude of classificatory significance of the concepts. Tversky and Gati present intriguing results demonstrating that the degree of judged difference between two concepts is not necessarily symmetrical; A toy train, for example, is commonly judged in controlled experiments as more similar to a real train than the real train is judged as similar to the toy train. Their explanation is that the most salient concepts become psychological bench-marks, standards, or anchors against which other "lesser" concepts are contrasted. The concept of the real train has more salience than that of the toy train, because the former is composed of a larger number of salient features having diagnosticity (general memory-classificatory significance) for the individual.

Rosch (1978) postulates that the "cue validity" of an attribute for a category increases as a function of the conditional probability of its association with that category, and decreases as a function of its association with other categories. The validity of a category is defined as the sum of the cue validities of the attributes making up the category. She presents results showing that subjects typically arrange categories in hierarchies, and identifies a "basic" level in the hierarchies for which the categories have higher validities than categories in either superordinate or subordinate levels. As compared to the basic level categories, superordinate (more generic) ones have fewer common and more distinguishing attributes, while subordinate categories have fewer distinguishing and more common attributes.

In terms of the cognitive model for intelligence analysis, the above results and discussion perhaps fit best into the categories/relation slot of the memory frame diagram, although the categorization principles undoubtedly apply to others of the slots as well, i.e., the sensory image slot, the behavior production slot, and the process pattern slot. That attribute diagnosticity or cue validity are of general functional importance in learning is also indicated by the discussion summarizing the findings of Spyropoulos and Ceraso (1977) in which they conclude that a cue fragment is effective if it acts as the identifying property of the total unit, and that such reintegration depends on the degree of unity achieved during initial perception. That cue diagnosticity applies to visual images stored in the sensory image slot of the memory frame diagram is shown by Bower and Glass (1976). They found that certain types of fragments of nonsense line drawings were superior cues for recalling the whole drawing of which they are parts. These cues corresponded to larger structural units of the graphic image when such units were defined in terms of gestalt principles Koffka (1935), Kohler (1940, 1947).

Internal organizational aspects of the time locale slot of the memory frame diagram are suggested by the findings of a number of authors. McTaggart (1927) noted two frameworks within which positions in time are embedded. Each position is in the past, present, or future; and, each position is earlier than some others, and later than some others. Rescher and Urquhart (1971) analyze the meaning relations between such terms as past, present, future, now, later, and earlier through use of a system of axioms of temporal logic expressed in the form of a predicate calculus. The analyzed relations between terms can be graphically mapped onto a time line which, presumably, could be projected onto the Gregorian calendar and clock system of time coordinates for a particular set of identified events.

Blankenship (1974) postulates that there are no important differences in the ways in which memory for events and memory for concepts are encoded in long-term memory:

In particular, it is assumed that the process of encoding information in long-term memory does not automatically incorporate information about when the storage took place. As a result, judgements of the sequence of events must be an inferential process based on information retrieved about events, together with processing rules that reflect the order in which certain classes of events, or events that have certain properties, have generally occurred in the past.(p 2)

Using several independent methods of assessing subjects' knowledge of the order of occurrence of events, he found that sequence judgments made witn a reliable rule available were much more accurate than those made without the benefit of such a rule.

Kihlstrom (1979) used posthypnotic amnesia as a method for probing the organization of recall in episodic memory. He notes that recognizing items presented in earlier episodes involves the reconstruction of the spatiotemporal and experiential context in which the item appeared, and that it is this step which appears especially difficult during posthypnotic amnesia. The loss of contextual cues impairs complete reconstruction of the original item/event, and thus impairs recognition of the item. He summarizes:

These findings are leading us to shift our metaphor for memory from "search" to "reconstruction", and our metaphor for amnesia from "disorganization" to "dissociation". (p 13)

In this view, memories for temporal relations are associated more closely with episodic context or "ground" traces than with item/event "figure" traces. It is interesting to speculate whether the temporal inference rules suggested by Blankenship usually operate more definitively on the contextual aspects of memories. The observations discussed earlier of Baddeley and Hitch (1977) regarding the dependency of the recency effect on number of similar intervening events seem pertinent here.

The linkage in the cognitive model memory frame diagram between the sensory image slot and the affective/valuative slot is highlighted by the findings of several investigators. Schwartz (1976) and Brown and Kulick (1977) discuss the manner in which a strong affective/valuative component for an experience may distort or reverse the normally expected process of re-encoding sensory images as semantic categories in long-term memory (the categories/relations and process pattern slots). In "flashbulb" memories, the strong affective/valuative component of the original experience appears to be related to a shift of the encoding process away from converting the sensory information mainly to semantic categories, and toward increasing emphasis on continued storage of the sensory information in a long-term representation very like the sensory experience itself. Similarly, Keenan, MacWhinney, and Mayhew (1977) and Kintsch and Bates (1977) observe that while the verbatim surface aspects of sentences are normally lost from long-term memory (see Till earlier), terms and phrases linked with high affective overtones, such as wit, sarcasm, and personal criticism, show a significantly stronger tendency to be remembered verbatim. This effect is not simple however. Rogers, Kuiper, and Kirker (1977) replicated earlier results showing that increased degrees of semantic-oriented processing (meaning contents-oriented processing) produces increased retention in long-term memory, ranging from syntactic levels, through phonemic (sound) repetitions, through synonymity produced by adjective pairs, to the most powerful treatment which used affect/value referencing personal description adjectives and required subjects to judge their applicability to themselves.

To summarize: Research results and theoretical formulations can be cited to support each feature of the concept of node-link memory frames as described in the cognitive model. This includes the ideas of hierarchical organization by level of specificity of information, relational linkages between different kinds of information, and a general figure-ground or context-item type of organization.

3.3 Elemental Dynamic Processes

The elemental dynamic processes of the cognitive model are basic Match/Decode/Match/Encode (MDME) sequences operating both within and outside awareness to process inputs from sense reception and/or from memory contents against the contents of memory. Miller (1956) was an early proponent of a coding concept of cognitive processing that introduced the idea of hierarchically organized "chunking" of the input, and noted an apparent limitation of about seven plus or minus two chunks that could be consciously processed for any given level of the hierarchy. Wickelgren (1967) observed that the optimum chunk span was somewhat less than Miller's maximum, finding that the easy optimum at any level is three chunks, and that subjects tend to resist the use of four or more chunks. Johnson (1972) used a similar concept and postulated that, from the point of view of the conscious processor, each level of hierarchy in the memory code is "opaque" with respect to the other levels. He noted that during recall production, subjects make decoding decisions for a chunk before producing any item from the chunk, and terminate recall if uncertain of any item in the chunk. Graesser and Mandler (1978) found that the maximum span of apprehension of naturally occurring categories is five plus or minus one, and that when the limit is reached there is a pause and a new entry point is sought. The above range of ideas provide the basis for the basic MDME metaphor of the cognitive model.

Goldman and Pellegrino (1977) found that proliferated multiple encodings of an item are partially additive for increasing later recognition and recall, and that repetition of deeper level (more detailed) encodings benefited retention more. Griffith (1976) compared the effects of mnemonic "reminders" supplied by the experimenter and invented by the subject. The latter required more capacity to form, but required less attention and produced better recall. Anderson and Reder (1978) define the deeper, memory reinforcing levels of processing as the production of a greater variety of more elaborate patterns of memory encoding. Brandsford, Franks, Morris, and Stein (1979) summarize the discussion of a range of such findings and concepts with the idea of "transfer appropriate processing" --that memory accessibility is a product of an interaction between encoding elaboration on the one hand, and on the other, the degree of compatibility between encoding patterns for the initial storage and the access cycles. Craik (1979) points out that retrieval cues are effective to the extent that they induce operations, or records of operations, that match the original event-as-encoded. He senses a growing agreement that retrieval processes are quite similar to encoding processes in many respects and may even be identical. This summary view is reflected in the mechanics of the elemental MDME processes depicted in the cognitive model.

3.4 Memory Modification Mechanisms

The memory modification mechanisms depicted in the cognitive model do not include the hypnotic-suggestion-based, memory-partitioning, dissociative phenomena described in the present chapter. On the basis of the evidence for ready every-day mobilization of partial dissociations (e.g.,divided attention) and the data on hypnosis-induced dissociations, it seems reasonable to expect that, especially under pressing circumstances, dissociations of varying strengths, having been induced by suggestions and/or by wish-fulfillment mechanisms, may play significant roles in the memory availability patterns of many normal individuals. However, this topic will not be pursued further in the context of the present effort because of limited time and resources.

The three elements of the Information Contents Modification Cycle shown in Figure 2-2 are: Sensory Information Filtering; Memory Contents Consolidation; and, Memory Access Interference.

3.4.1 Sensory Information Filtering

In the earlier discussion of the senses, Gibson's summary points were used to portray the current view that sensory reception and experience are active rather than passive processes, that they involve intimate and continuous use of contents from long-term memory, and that wide-spread activities throughout the brain are necessary for their support. The immediately preceding discussion of elemental processing mechanisms (MDME sequences) culminated in the view that encoding (storage) and decoding (search) processes are very similar if not identical. These established points provide the framework for asserting that sensory information filtering occurs within the confines of the MDME process. Information selectivity and generalization filtering actions are both determined by the momentary relationship between the information pattern in the sense reception input and the information pattern matched and decoded (actively constructed) from long-term memory. Information elements from the sense reception pattern may be missed or highlighted, used with a good fit or a poor one, and be "smoothed" by additions of missing elements from memory information. The criteria used for such automatic operations is the pattern of information already existent in memory.

Perhaps the most ubiquitous evidence for selectivity and generalization filtering has come from the clinical use of "projective" tests. One does not have to espouse the details of projective theory or of personality and motivational interpretations made from their results to appreciate the nature of the massive evidence they afford for selective filtering of sense reception inputs. Examples of all the forms of information filtering posited in the cognitive model can be seen in responses to picture-scene and inkblot types of tests. The under-structured "projective" stimulus patterns are combined (encoded) with the individual's mental contents, and an experience varying from individual to individual is generated. The particular aspects used from the available stimulus pattern depends upon the particular contents of the individual's memory that are potentially mobilizable, partially mobilized, and fully mobilized when the sense reception input arrives.

Through such mobilization factors, specialized knowledge often controls selective information filtering. At a cocktail party, a physician's mobilized memory contents may lead him to "see" a woman's forward-swung shoulders as the early signs of a form of muscular dystrophy, while others are commenting on the resemblance of her shoulders to the stylish ones of a famous actress of the past. A musician recognizes "borrowings" in the melodic line of a new piece of music unrecognized by others. An engineer is dazzled by the unusual and clever design of a new text-processing machine, viewing it as an inevitable financial bonanza, while a marketing researcher views it as just another fancy gadget to do something already done very well by other means.

The importance of the momentary situational context on selective encoding of the sensory reception input is emphasized by Jacoby and Craik (1979) in presenting their concept of encoding distinctiveness. They point out that a careful review of word sense usages will make it apparent that there are very few "exact" synonyms in english. At the same time, many words operate as functionally equivalent meanings in a given context, as in their example of a driver hearing the exhortation "Watch out for the ______(house, tree, truck, bicycle, train, etc.)". The encoding distinctiveness concept holds that the meaning of a sense reception input is a set of contrasts resulting from the distinctions required for interpreting the input within a certain ongoing dynamic context (episode). Meaning is not simply an attribute that is or is not encoded. Rather, it is the actively constructed result of setting up or emphasizing aspects of the stimulus input that provide contrastive information to distinguish the input from the background commonality of a certain momentary context.

Expectations operate selectively to emphasize some kinds of contrastive information over others. Wickelgren (1979 pp 116-117) provides examples from hearing spoken words. People will, for example, rarely notice anything wrong with a new-day greeting of "Could borning" if it is followed immediately by continuing comments. Warren (1970) replaced the "gis" syllable in "legislatures" with a cough, tone, or buzz. Subjects were unable to distinguish (to contrast) the altered word from the normal version. In effect, such expectations operate not only to filter out incorrect syllables but to fill in missing correct ones. Correct expectations employing the same kinds of mechanisms can facilitate the speed and accuracy of picture recognition (Pachella 1975). In general, the input-filtering mechanisms of expectations are active "constructive" processes guided by highly organized contents from memory.

Selection and generalization mechanisms are also evident in the contents of communications between individuals. Both selection and generalization occur in the use of metaphorical expressions, subtle versions of which are extremely frequent in much human communication. Ortony (1975) proposes that metaphors serve communicative needs by being "compact" and by carrying contents that are "inexpressible" in other ways. A metaphor is compact in that it can transfer many properties at once from an already established domain to a new one. Many of these properties may be inappropriate to the new domain, and other properties needed for the new domain may be missing, thus providing the conditions for generalization and selectivity. There are many combinations of semantic properties for which we have no name and no concept (i.e., the combination is inexpressible). A metaphor can be a practical means of communicating such a combination of properties that are not yet well enough analyzed to be named or described conceptually. Again, such conditions are ideal for generalization and selectivity.

Sternberg (1977) presents a theory of analogical reasoning involving the process components of encoding, inference, mapping, application, justification, and preparation-response. Although wide variations in the use of these components were observed, no consistent individual differences in the particular differential emphasis and pattern of their use were noticed over a range of experimental settings. The chances for serial unreliability seem great in the sequential operation of such a set of components, and large random differences in generating and understanding analogies can be expected. Put in other terms, the opportunities are great for introduction of "noise" in interpersonal communications through selectivity and generalization effects implicit in analogies.

3.4.2 Memory Contents Consolidation.

The discussion of the cognitive model asserts that memory contents are made more accessible and vivid as a joint function of the frequency of processing and the amount of attention used in processing. The effects of increasing the depth and/or proliferation of encoding of the sensory reception input for increasing retention were reviewed earlier. The effects of increased number of repetitions of "practice" for increasing retention are well known in everyday observation and have been confirmed by literally thousands of experiments in animal and human learning. However, retention and strength of learning can increase without apparent practice under certain conditions, and this has prompted the theoretical concept of internal rehearsal and "consolidation" of the contents of memory. Hockey, Davies, and Gray (1972) show that memory is better following a retention interval containing sleep than one not containing sleep. Whether this is due to conscious rehearsals performed while falling off to sleep, to automatic rehearsals during sleep, to the reduction of wakeful interference effects attendant upon sleeping, or to a combination of these effects is not clear at present.

The strength of the initial memory trace for the sensory input pattern appears to be established very rapidly, within seconds. On the other hand, the apparent increased retention afforded by the consolidation process appears to be the result of increasing the depth and range of encoding relationships (retrievability) between the sensory input pattern memory trace and the rest of memory contents, rather than further strengthening of the original memory trace (Miller and Springer 1973). Mandler (1978) distinguishes between integration and elaboration in the consolidation process. Integration improves the item's cohesiveness, while elaboration increases the item's connections with other ones. Anderson and Bower (1972, 1974) propose a two-process theory of generation-recognition, in which the item is the eliciting stimulus and the context information stored from the original learning episode comprises the response. Recognition involves recovering information concerning the time/place context of occurrence of the original item in greater or lesser degrees of detail (Watkins, 1974, Watkins and Tulving 1975).

Retrieval/retention effects induced by consolidation appear to be governed by the kinds of highly organized, contrastive mechanisms operating between the sensory reception input and memory contents discussed earlier. Bartlett's (1932) classic book introduced the idea of a mental schema (frame) to account for the results of experiments in which subjects studied a printed story and were then asked to reproduce it on several later successive occasions. No corrective feedback or further opportunities to study the story were given. Culturally unfamiliar stories, such as an american indian story entitled "The War of the Ghosts", produced the most dramatic examples of progressive changes in successive reproductions of stories. Reproductions were usually shorter, more concrete, used more modern phraseology, and unfamiliar terms dropped out (a non-contrastive "leveling" action). On the other hand, some shocking, weird, or unlikely (highly contrastive) details tended to be retained and even elaborated (a "sharpening" effect). Bourne, Dominowski, and Loftus (1979) note that when subjects hear a story, they usually do not remember portions of it which do not fit into their existing long term memory structures (p 85). Allport and Postman (1958) noted similar effects in memories for pictures, with distortions of the picture memories fitting social stereotypes presumed to be contained in more incorporative memory structures (such as remembering a straight razor actually pictured in the hand of a white man as being held by a black). Both the subtle and extreme forms of such contrastive distortions can be understood as forms of "caricature".

3.4.3 Memory Access Interference

The intervening similarities and similarities saturation types of interference described in the cognitive model are meant as lay-descriptive re-namings for the retroactive and proactive inhibition effects. Melton and Irwin (1940) proposed that retroactive inhibition was composed of two factors: 1.) The intrusion of new, interpolated learned responses in conflict with the earlier ones, and 2.) The extinction of the earlier responses as a result of not being reinforced during the interpolation trials. Barnes and Underwood (1959) used the learning of lists of paired words to demonstrate retroactive inhibition. They showed that subjects recalled the response words associated with a decreasing percentage of the cue words from an original list presented a second time, depending upon how many intervening practice trials they had been given on an "interference" list which presented the same cue words as the original list but required different response words.

Underwood (1957) invoked the concept of proactive inhibition to explain why about 75% of the items on a criterion list of words learned to one perfect trial could not be recalled after 24 hours, even though no interpolated interference learning trials had taken place. He showed that the number of highly similar lists learned shortly before learning the criterion list, would predict the amount of lost recall experienced for the criterion list. If the subject had not recently learned such highly similar lists, there would be an average of only about 25% loss of recall in 24 hours, rather than 75%. In other words, memory contents for the earlier similar lists were creating interference effects which cumulated during the 24-hour retention period in which no new list-learning activity had taken place. These and many similar results suggest that for learning taking place under highly repetitive, redundant circumstances, it may be safely assumed that pro-active inhibition will be present to a significant degree, operating on both item information and context information. Some types of intelligence processing under high load have this character.

Wickens, Born, and Allen (1963) introduced the concept of release from proactive inhibition and demonstrated its effects. They hold that the loss in recall caused by preceding items is in effect a loss of encoding distinguishability among current items. A change of pace or "break"--a change in the type of items to be encoded-- has the effect of "releasing" or reducing the interference effect, the more difference between the "break" items and the inhibited items, the stronger the effect. O'neill, Sutcliffe, and Tulving (1976) show that for such release to take place, the "break" item must be discriminably encoded in memory, and an appropriate stimulus item must be presented. In other words, a random, "meaningless" distraction will not do as a break item; subjects must be presented with an alternative they can "get their teeth into". As could be anticipated from the contrastive view of encoding discussed earlier, Gardiner, Klee, Redman, and Ball (1976) show that the degree of release reflects the relative contrast between the "break" and "proactive" stimulus encodings, and that such contrastive effects also appear to be hierarchically organized in encoding patterns.

3.5 Complex Behavioral Processes

The cognitive model serves as a framework within which to consider more complex cognitive processes usually involved in intelligence analysis activities. Such complex cognitive processes include problem-solving and decision-making in the service of performing the three generic types of tasks identified for intelligence analysis:

1. Making interpretations.
2. Managing resources.
3. Adapting to change.

Problem solving involves the making of decisions, and decision-making may involve the solving of problems. Problem solving of a particular kind can be viewed as the orchestration of a behavior plan or program (a la Miller, Newell, Anderson), the use of memory information unique to the problem area, the utilization of relevant generalized processing skills, and, the invoking of decision criteria. Selected examples of research bearing on each of these ingredients is presented in the following sections.

3.5.1 Problem Solving

As summarized earlier from Wickelgren (1979), behavioral plans/programs usually consist of a partially ordered set of actions and their consequences. Both the actions and consequences are embedded in and/or constructed of memory information for the particular environmental contexts, situations, objects, and event classes within which the behavioral plan is to be carried out. There is usually an intimate, often inextricable interweaving of the actions/consequences information and the contextual supporting information (Schank and Abelson 1977). A corrolary is that to support highly practiced planned/programmed behavior, the contextual supporting information must first be encoded deeply and widely (i.e.,proliferated), and second, this information must be readily accessible to (elicitable by) the partially ordered actions/consequences information also stored in memory. Games involving complex problem solving provide examples of these necessary conditions.

Hayes and Simon (1977) discuss "problem solving isomorphs" for games such as Tic-Tac-Toe, Missionaries and Cannibals, and Tower of Hanoi. Game isomorphs are constructed by disguises or "cover stories" that alter the apparencies of the game but leave the logical structure intact. Transfer of skill from performing one isomorph to another is not reliable; insights gained in more difficult games are sometimes applied to simpler ones, but the reverse is much less true. The sensitivity of the actions/consequences programs to the particular information available from the supporting context is also shown, for example, by large performance impacts that can result from framing game instructions in the active versus the passive voice (Johnson-Laird, 1968).

de Groot (1965) observed the extraordinary degrees of flexibility and summarizing power (efficiency) of memory encoding patterns developed by highly skilled game players for information from the supporting context. Chess masters could reconstruct 90% of the positions from a game (approximately 25 pieces) after having seen it for 5 to 10 seconds, while under the same condition weaker players averaged 40%. With random board settings, however, the chess masters did little better than the others. Charness (1976) showed that memory for chess game positions is not encoded in short-term memory. Thirty seconds of distraction activity following the viewing of the positions reduced recall of the positions only 6%, although subjects took much longer to "reconstruct" the positions. Making essentially the same point, Frey and Adesman (1976) found that highly skilled chess players could recall almost the same percentage of positions from observing two positions as from one. Evidently the unique patterns represented by the positions were very rapidly matched with highly encoded memory structures, decoded ("recognized" as "fitting certain patterns"), and re-encoded as instances of those patterns (following the formulation given in the cognitive model).

The intimate relationship between actions/consequences (plans) information and supporting context information is further suggested by the idea that the two types of information are stored in very similar memory structures. Plans are structurally very similar to the episodic memories representing sequences of related events. Watkins and Tulving (1975) note that the node-link frames which organize semantic memory may be either topical (as in a hierarchically organized text-book on a topic) or episodic (as in a script involving that topic). The solution to a problem combines the use of both topical and plan/episodic information in a coordinated fashion. Moreover, before a solution can be attained a description of the problem must be assimilated and understood. This description must be representative of, and consistent with, the combined topical and episodic information necessary for solution. Typically, an "understanding process" which develops and assimilates such a description precedes the solution phase (Greeno, 1976). Skill in the proper placement of the understanding process is itself a form of episodically organized knowledge. Failure to solve a problem can result from inadequate encoding of relevant episodic (plan) information, of topical (problem context) information, or of both (Norman and Bobrow 1975). Positive and negative transfer of solutions between problems can also be based on generalizations of either kind of information.

Bourne, Dominowski, and Loftus (1979) summarize the major aspects of problem solving:

1. *Attention to environmental information is limited and selective.*

2. *Performance on a task is a joint function of the quality of the data available and the allocation of processing resources. Both immediately available environmental information and content held in short-term memory (STM) constitute data. There is some limit to the processing resources available; when task demands exceed this limit, performance is likely to decline gradually, although performance may show abrupt failure under certain circumstances.*

3. *Processing resources are required to maintain content in STM. Maintaining content in STM and operating on that content compete for the limited resources available.*

4. *Information is both entered into and retrieved from long-term memory (LTM), which has unlimited capacity. Entering information into LTM requires processing resources, and, while some information in LTM is retrieved with minimal processing demand, retrieval may fail.*

5. *The major processing steps in problem solving occur in an essentially serial (rather than parallel) fashion. (p. 236)*

3.5.2 *Quantitative and Spatial Processes*

It is evident from casual observation that quantitative and spatial thinking often play parts in the cognitive processes involved in solving problems in intelligence analysis. The question is, what is the nature of these thought processes? Calder (1979) reviews the history of professional mathematical thought in addressing the question of whether mathematics is discovered or invented. His discussion portrays the dependencies of later mathematical concepts on historically earlier ones, and shows that mathematical concepts can be developed both with and without regard for "reality". He espouses a constructivist position which holds that mathematics can have real meaning only if its concepts can be constructed by the human mind. The algebraic, geometric, and trigonometric conceptual tools used in some types of intelligence analysis tasks fit well into this constructivist view. Observations of the learning of mathematics and of the processes of detecting and correcting performance errors suggest that the gross steps in the cognitive processing of applied mathematical tasks are usually quite isomorphic with the operations depicted in the text books. However, many problem-solving and judgemental tasks in intelligence analysis appear to involve the use of less formally specified quantitative and/or spatial concepts and images. A question arises as to the nature of such informal cognitive patterns and the processes utilizing them.

Through analyses of combinations of rating scale judgments Anderson (1979) shows that loosely "algebraic" cognitive processes control the judgments. In the well-known weight-size illusion, an "adder integrator" combined the weights and heights of judged cylinders into a linear combined judgment of their heaviness. A "multiplier" process produced a "linear fan" of functions for subjective expected values for events, which combined their subjective values and their subjective likelihoods. In discussing the linear fan pattern of findings, Anderson cites an experiment of Oden (1977) on assigning animals (penguins, sparrows, ostriches, bats) values of "birdiness". Using a factorial design involving animals of different degrees of birdiness, Oden obtained the linear fan pattern of results. These results support a multiplicative rule for the elements of a semantic compound in predicting the degree of truth for assigning the compound to a certain semantic category. This also supports the concept of truth value as a continuous value in semantic theory (Zadeh, Fu, Tanaka, and Shimura 1975).

Sheppard and Metzler (1971) obtained results consistent with the idea that subjects' mental images of solid objects they were asked to "rotate mentally" did in fact undergo a mental rotation in real time. Rotational "problems" were presented in both the depth plane and the visual surface plane. Subjects were asked whether various pairs of objects constructed of cubes and set at various angles to one another could be rotated into one another. The decision times were linear on the degree of mental rotation required to "test" for the answer by mentally rotating the objects. For tasks similar to those of Sheppard and Metzler, Cooper (1976) found individual differences in mental rotation speeds, as well as individual tendencies to use either rapid "holistic" or more belabored "analytic" approaches to the judgments involved in the mental rotation tasks. These differences may be related to individual differences in lateralization--the more dominant use of one cerebral hemisphere "processor" over the other (Restak 1979, p 173-85).

3.5.3 Sampling Concepts and Probability Judgments

The complex, generalized concepts that individuals may use to evaluate the quality and extent of information available to them, and the bearings it may have on predicting anticipated events, seem of obvious importance for cognition. A number of studies show that the intuitive concepts of sampling and of probability used by most persons, including many with formal training in statistics, do not square well with the rigorously developed versions of these concepts (Tversky and Kahneman 1971, Kahneman and Tversky 1972, Tversky and Kahneman 1974, Estes 1976). Kahneman and Tversky found that the intuitive understandings of probability, chance, likelihood, etc. deviate systematically from probability theory: The ratios of events, types, members, in a particular sample of experience tend to be taken as values for the "universe", with little thought for sampling variation or the size or power of the sample. The statistical independence between series of uncorrelated events is not grasped, so that an unlikely string of events often causes "corrective" predictions based on anticipations of restored "normality" in the short-term distribution of events. More "representative" (balanced) samples are expected to occur more frequently than less "representative" ones (though they do not). That is, the "centroids", "idealized types" "stereotypical examples" "most salient categories" or "basic level" categories of encoded memory (see Evans, Hull, Bransford and Johnson, Tversky and Gati, Rosch, earlier) are anticipated to be more likely to occur than deviations, even in cases where the "ideal" configuration has never been experienced. Tversky and Kahneman (1971) propose that people use the amount of mental effort required to imagine or envision an event (its comparative inaccessibility in memory) as a yardstick for estimating the comparative likelihood or probability of the event. Estes (1976) showed that when provided with "statistical data" on types of events, people tend to base their estimates of future event likelihoods on the comparative frequencies provided for them, ignoring more refined considerations regarding whether they have received a fair and unbiased sample.

3.5.4 Decision Making

The quantitative, sampling, and likelihood processing characteristics of normal cognition as described above represent conceptual tools that may be used in problem-solving activities aimed at the making of decisions under conditions of uncertainty and risk. Among models of rational decision-making under risk, Bayes' theorem has held center stage for almost two decades of laboratory research in decision-making. Bourne, et al ask the question Are people Bayesian? and provide a summary answer:

--people seem to agree at least in positive/negative terms with the formula's predictions. When the evidence or data should lead to lowering a probability, subjects tend to lower it; when the data should lead to raising a probability, subjects tend to raise it. In general, however, people do not change probabilities as much as Bayes' theorem indicates they should--they are conservative.--However, recent evidence indicates that the way in which people intuitively process probabilistic information may have little or nothing to do with formal theory. (1979 p.292)

Kahneman and Tversky (1979) present "prospect theory" as a more accurate model of observed choices among risky prospects, in which the choices are inconsistent with the basic tenets of utility theory. People underweight prospects that are probable in favor of those that are certain. In weighing prospects, aspects shared by all prospects are ignored, which can lead to inconsistent choices among the same prospects when presented in different contexts. In the prospect model, decision-making is broken down into a series of steps or phases comprising a problem-solving process, with the perceived decision situation being cyclically re-encoded in terms of prospective gains and losses viewed from each particular process reference point as it is reached. The process is a cycle of information editing and information evaluation phases, broken down into several steps. First, the decision-information is encoded in gain/loss terms from the initial reference point. Components are then combined or "lumped" for simplification. No-risk components are segregated out. Factors common to the various prospects are cancelled from further consideration. Very low probability prospects are dismissed. Finally, the remaining dominant prospects are compared and "weeded", and the cycle may be repeated. The result of this process is a value function that is normally concave for gains, convex for losses, and usually steeper for losses than for gains.

Payne, Braunstein, and Carroll (1978) present a process tracing approach for the investigation of "predecisional" psychological processes that lead to decisions. The method aims to identify the information available to the decision maker and how it is psychologically processed during the predecisional period. The tracing method combines analysis of verbal protocols obtained by "talk-along" from the decision-maker, and observation of the decision-maker's concomitant information acquisition behaviors.

"Decision-builders" are affected not only by the amount and quality of available information and by their relevant problem-solving skills, but also by major motivation-related features of the decision-making context. Janis and Mann (1976) review a range of research centering on describing the conditions under which psychological stress imposes limitations on the processes of decision-making. They present a table summarizing the predecisional behavior characteristics of five basic patterns of decision-making: Unconflicted adherence, Unconflicted change, Defensive avoidance, Hypervigilance, and Vigilance. Each pattern is defined by its degree and pattern of incorporation of each of eight behavioral steps in the decision process: Thorough canvassing of alternatives, Thorough canvassing of objectives, Careful evaluation of consequence of current policy, of new policies, Thorough search for information, Unbiased assimilation of new information, Careful reevaluation of consequences, and Thorough planning for implementation and contingencies.

They present evidence that under conditions promoting defensive avoidance, decision-makers distort evaluations of alternatives both before and after they have made a decision, and that under conditions favoring vigilance, decision-makers remain open-minded both before and after they have made a decision. The decision-making conditions that tend to lead to the various predecisional behavior patterns are defined in terms of various combinations of information about five topics: challenging negative feedback or an opportunity; potential losses from continuing the present course of action unchanged; potential losses from changing the course of action; the availability of more relevant information and other unused resources; and, time pressures and a decision deadline. The authors also provide an extensive review of the results of various techniques of intervention designed to improve decision-making under the range of conditions studied.

4. SUMMARY

This review has considered research relating to the concepts incorporated in the cognitive model. The senses, sensations, and sense-perception were covered briefly and shown to involve central processes of meaning. The concept of a sensory buffer was elaborated from studies of iconic and echoic memory, both of which are phenomena involving long-term memory access and wide involvement of brain activity. The processing of information within and outside of awareness were depicted as being on a continuum between these two polarities, with processes outside awareness ordinarily operating rapidly and grossly on large quantities of information. Awareness and attention were shown to be controllable through aware conceptual activities of the individual as well as by automatic processes outside awareness. The phenomenon of dissociation or mental barriers was seen to be a powerful and undoubtedly widely distributed pattern of behavior.

The observed importance of memory functioning in the contexts of intelligence analysis work was underscored by the central position of memory in laboratory studies of cognitive functioning. The distinction between working and long-term memory was shown to be supported by a range of research findings. The comparatively unlimited capacity but sometimes problematic accessibility of long-term memory was constrasted with the limited capacity and more ready accessibility of working memory. The importance of working memory capacity limitations for problem-solving activities was highlighted by the focuses of a number of research studies.

Decision-making or decision-achieving processes were depicted as forms of problem solving. In the context of intelligence work, decision making often involves the use of concepts involving spatial, quantitative, probabilistic, and sampling considerations. Several studies were cited to show that informal cognitive behavior differs in systematic ways from formally derived theories for such concepts. Finally, the effects of various pressures on decision making were considered briefly.

Practical constraints of time and project resources limited the further pursuit of many of the concepts presented here. For the future, a number of topics seem especially deserving of additional attention. The recent focus on relationships between spreading-activation and levels-of-processing theories of memory functioning may help shed light on problems of cognitive functioning in intelligence analysis, especially if considered in the light of theories of the contrastive functioning of memory (in distinction to retrieval from slots). The apparent continuum from divided attention to massive dissociative barriers in mental functioning needs deeper consideration, especially in view of its apparent susceptibility to conceptual control by either the individual or by outside suggestions.

This array of memory-functioning topics needs to be considered in the framework of the particular kinds of problem-solving sequences of planned/programmed behavior that are involved in the making of information decisions in intelligence analysis. Within such a context of ongoing day-to-day activities, the various impacts of the memory-modification cycle might prove particularly amenable to observation and manipulation. As suggested in the recommendations of the summary report, the environ of an automated information support system for intelligence analysis could provide many of the conditions necessary for such study.

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